PYQ
SERIES

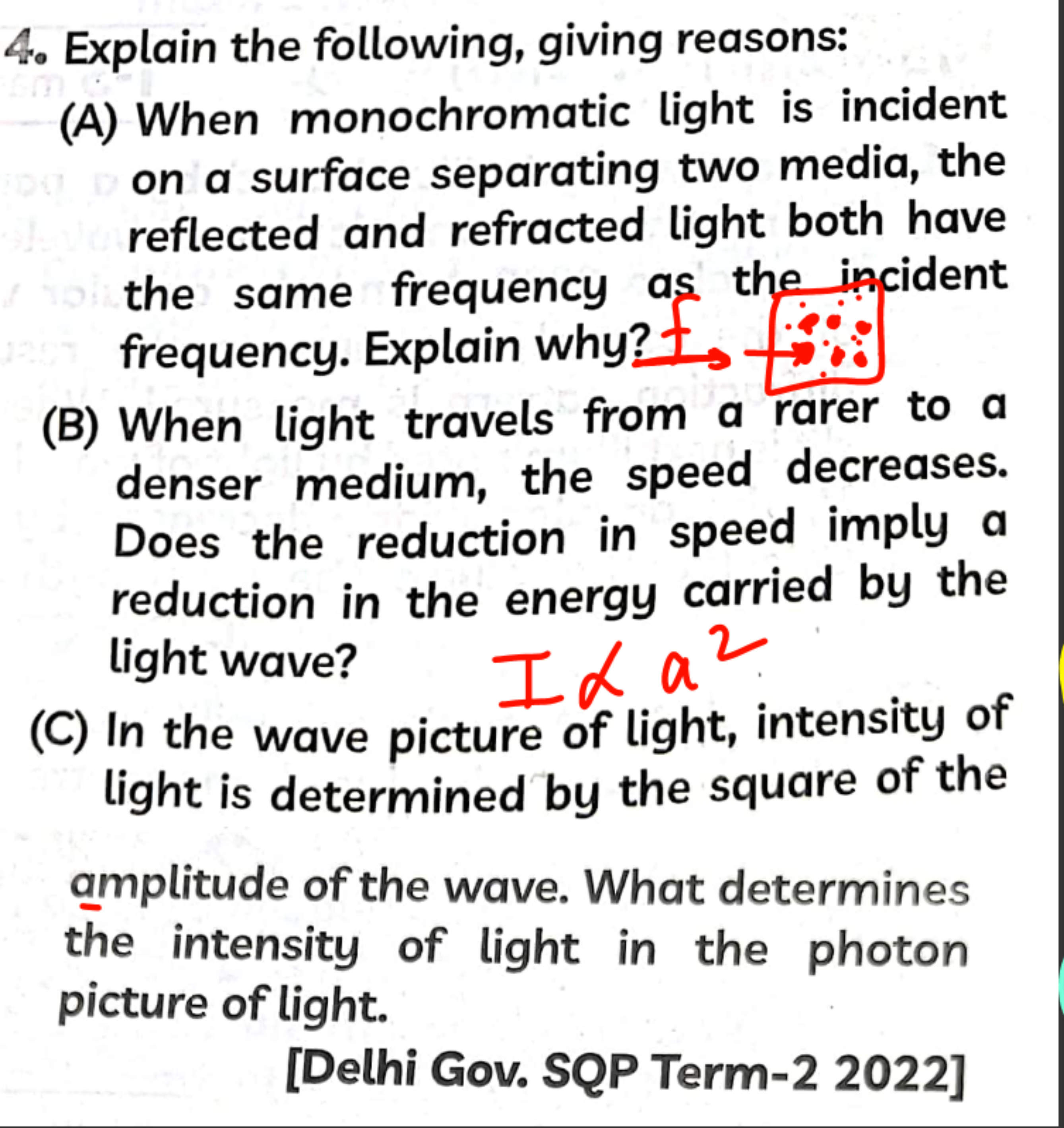
CHAPTER - 10

WAVE OPTICS

1. A ray of monochromatic light propagating in air, is incident on the surface of water. Which of the following will be the same for the reflected and refracted rays?

(a) Energy carried (b) Speed
[✓ (c) Frequency] (d) Wavelength

[CBSE 2023]



4. Explain the following, giving reasons:

(A) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency. Explain why? $f \rightarrow$

(B) When light travels from a rarer to a denser medium, the speed decreases. Does the reduction in speed imply a reduction in the energy carried by the light wave?

$I \propto a^2$

(C) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity of light in the photon picture of light.

[Delhi Gov. SQP Term-2 2022]

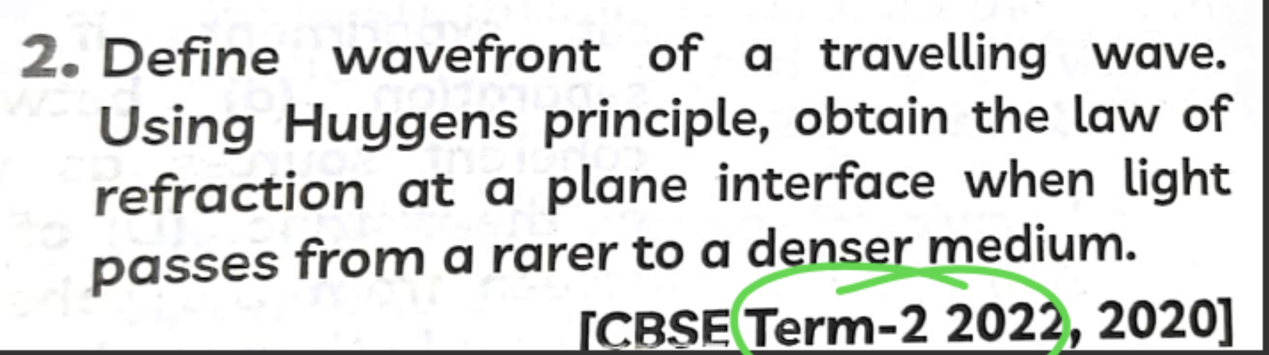
(a) Reflection and Refraction arise through the interaction of light with atomic constituent of matter which vibrate with same frequency as that of incident light. Hence frequeny remains same.

(b) Energy of wave depends on its frequeny. It does not depend on speed. So It will not change

(c) Intensity of light is determined by number of photons incident per second on the the surface.

freq → Energy

Intensity → P.E. current.

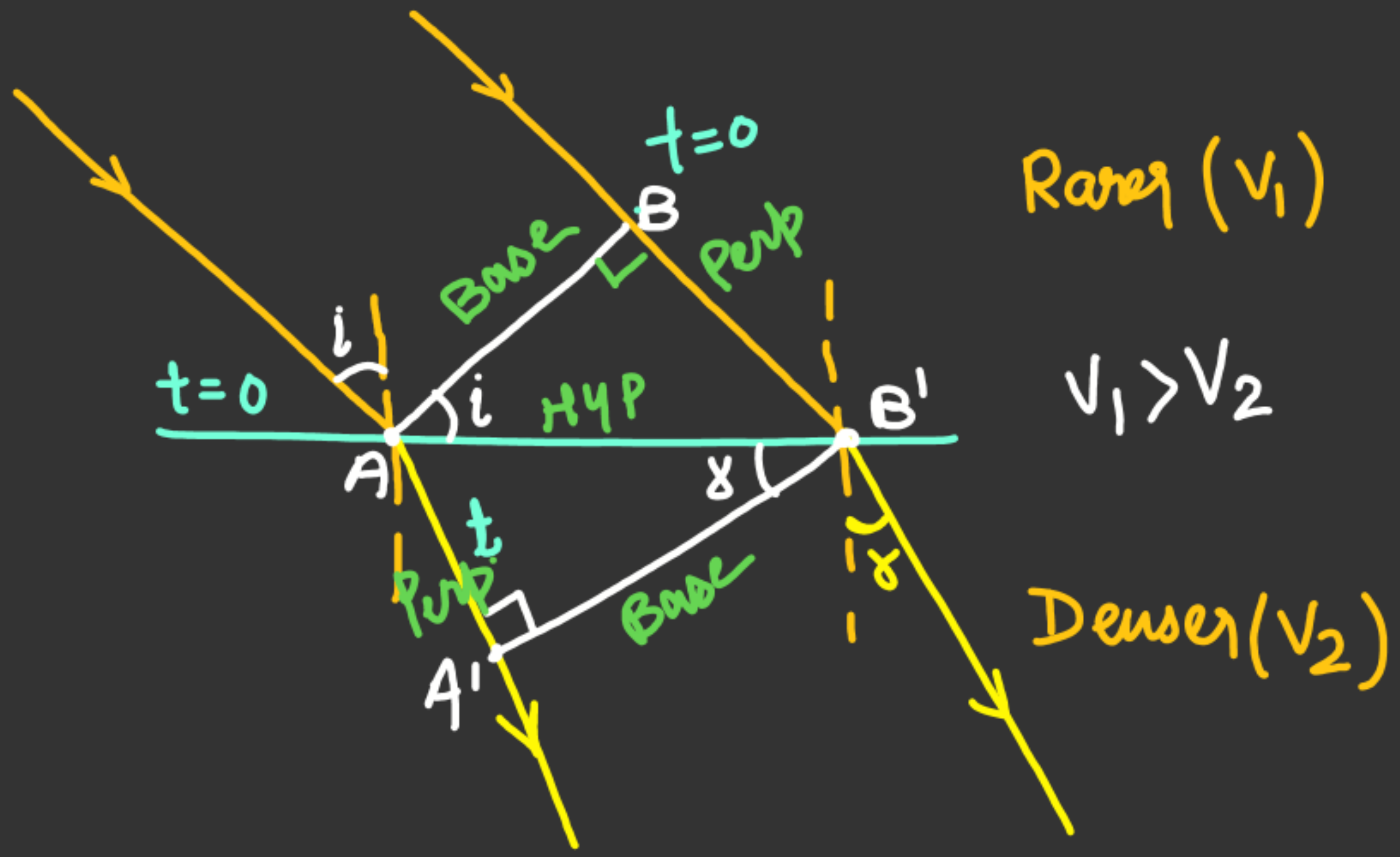


2. Define wavefront of a travelling wave. Using Huygens principle, obtain the law of refraction at a plane interface when light passes from a rarer to a denser medium.

[CBSE Term-2 2022, 2020]

wavefront

wave front is defined as the locus of all such particles which are oscillating in same phase.Normal to the wave front gives the direction of propagation of wave.at same time



$AA' = V_2 t$

$BB' = V_1 t$

In △ABB',

$\sin i = \frac{BB'}{AB'}$ — ①

In △AA'B'

$\sin r = \frac{AA'}{AB'}$ — ②

Devide eq ① by ②

$$\frac{\sin i}{\sin r} = \frac{BB'}{\cancel{AB'}} \times \frac{\cancel{AB'}}{AA'}$$

$$\frac{\sin i}{\sin r} = \frac{BB'}{AA'}$$

$$\frac{\sin i}{\sin r} = \frac{V_1 \cancel{t}}{V_2 \cancel{t}}$$

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2}$$

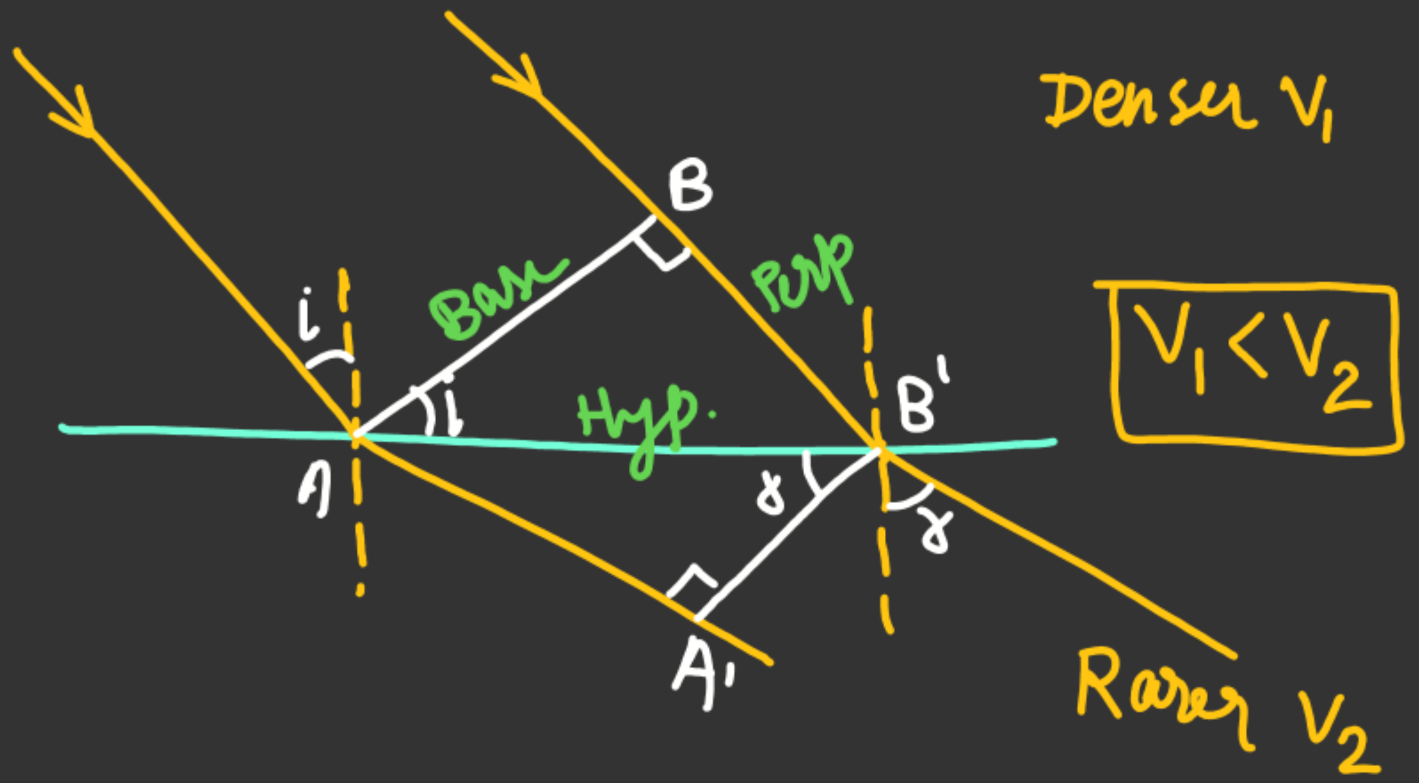
$$\boxed{\frac{\sin i}{\sin r} = \mu}$$

This is Snell's law.

3. Define wavefront. Draw the shape of refracted wavefront when the plane incident wave undergoes refraction from optically denser medium to rarer medium. Hence prove Snell's law of refraction.

[CBSE SQP Term-2 2022]

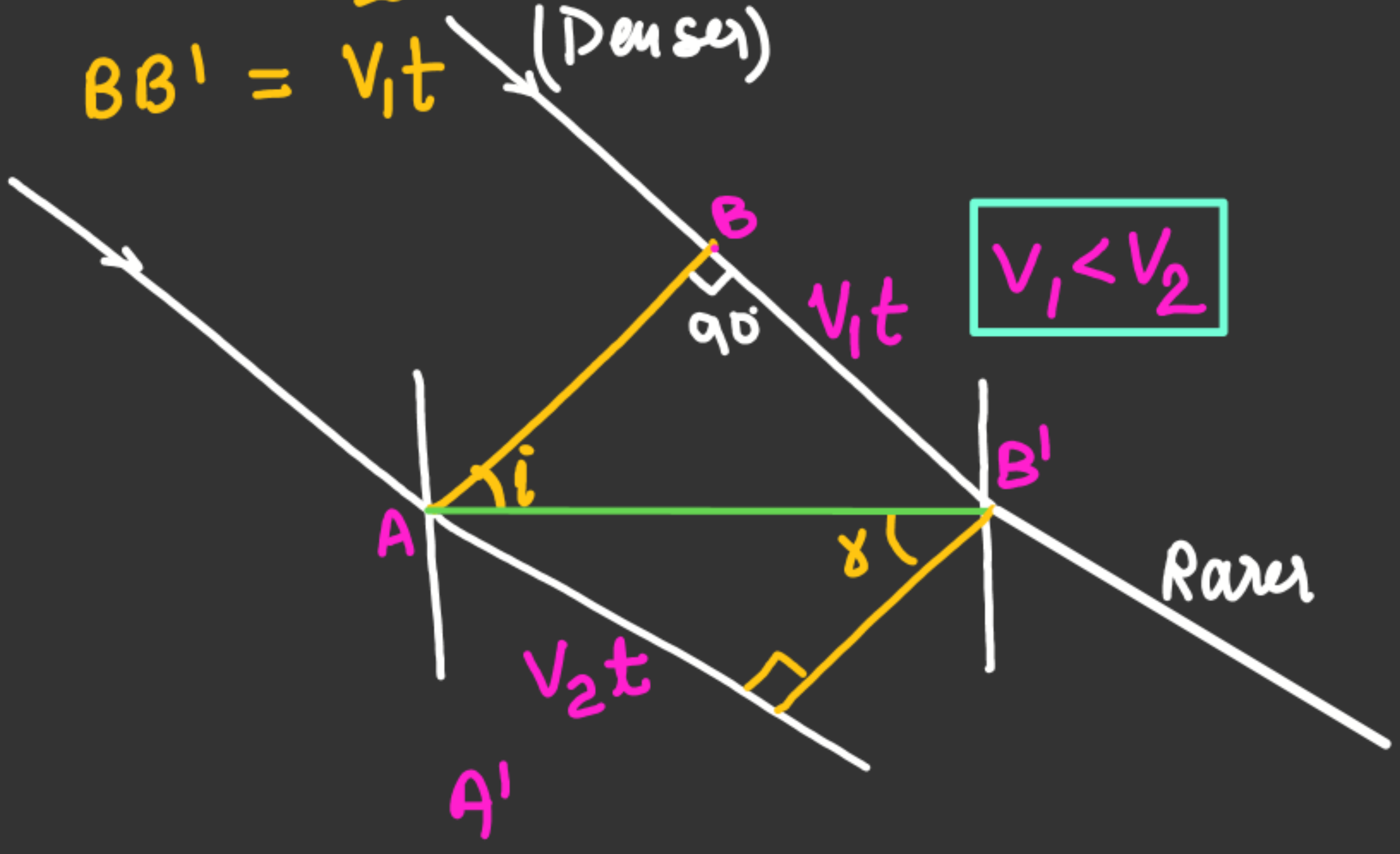
All steps are same as previous Que except diagram.



Prove law of Refraction on the basis of Huygen's Wave theory. (From Denser to Rarer)

$AA' = V_2 t$

$BB' = V_1 t$



In $\Delta ABB'$

$$\sin i = \frac{V_1 t}{AB'} \quad \text{— ①}$$

In $\Delta AA'B$

$$\sin r = \frac{V_2 t}{AB'} \quad \text{— ②}$$

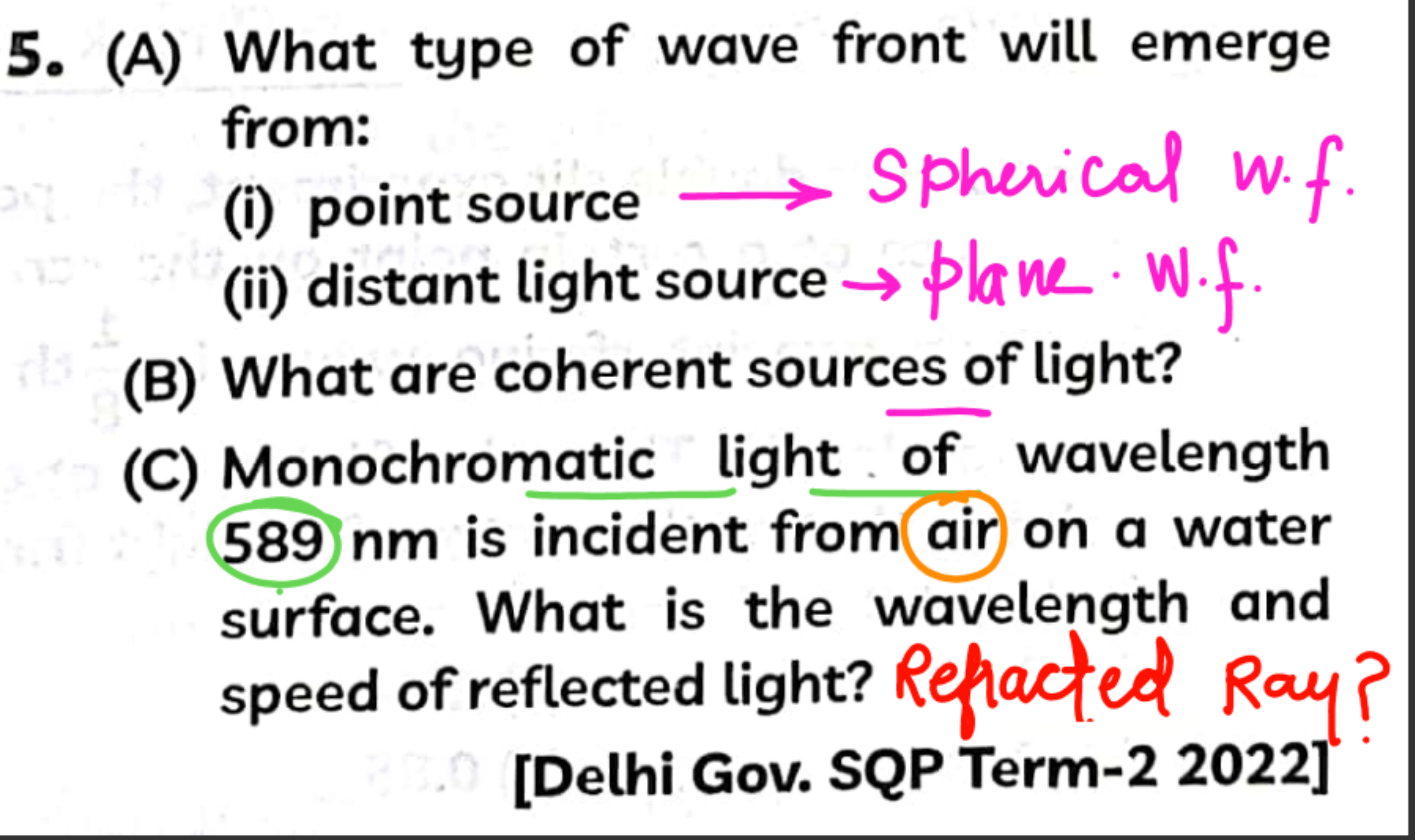
Devide eq ① by ②

$$\frac{\sin i}{\sin r} = \frac{V_1 t}{\cancel{AB'}} \times \frac{\cancel{AB'}}{V_2 t}$$

$$\left.\frac{\sin i}{\sin r} = \frac{V_1}{V_2}\right\}$$

$$\boxed{\frac{\sin i}{\sin r} = \mu}$$

This proves snell's law of Refraction



5. (A) What type of wave front will emerge from:

(i) point source → Spherical w.f.

(ii) distant light source → plane. w.f.

(B) What are coherent sources of light?

(C) Monochromatic light of wavelength 589 nm is incident from air on a water surface. What is the wavelength and speed of reflected light? Refracted Ray?

[Delhi Gov. SQP Term-2 2022]

(B) Those light source which produces light of same frequency, wavelength and are in same phase or constant phase difference. are called Coherent sources of light.

During reflection speed & wavelength of light will remain same.

$$\lambda = \frac{c}{\nu} \rightarrow \lambda_{water} = \frac{\text{speed of light in water}}{\text{frequency of light in water}}$$

$$\text{freq of light in air} = \frac{3\times10^{8}}{589\times10^{-9}}$$

$$= \frac{3\times10^{17}}{589}$$

$$= \frac{3000\times10^{14}}{589}$$

$$\text{fr. in air} = 5.09\times10^{14}\ \text{Hz}$$

frequency of light in air = freq. of light in water.

$$\lambda_{water} = \frac{\left(\frac{3\times10^{8}}{\frac{4}{3}}\right)}{5.09\times10^{14}}$$

$$= \frac{3\times10^{8}}{5.09\times10^{14}} \times \frac{3}{4}$$

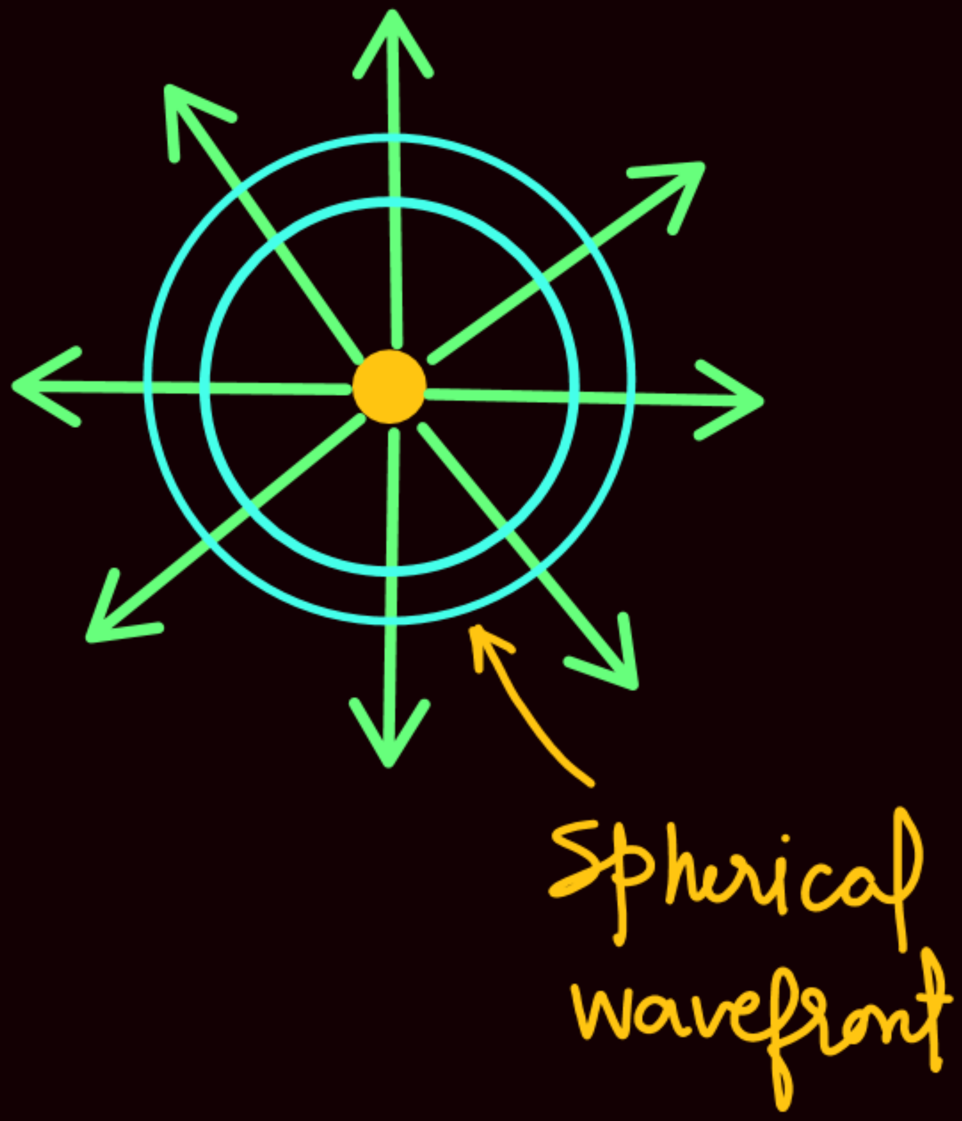
$$= \frac{9\times10^{8}}{20.36\times10^{14}} = \frac{9}{20.36\times10^{6}} = \frac{9\times10^{-6}}{20.36} = 0.44\times10^{-6}$$

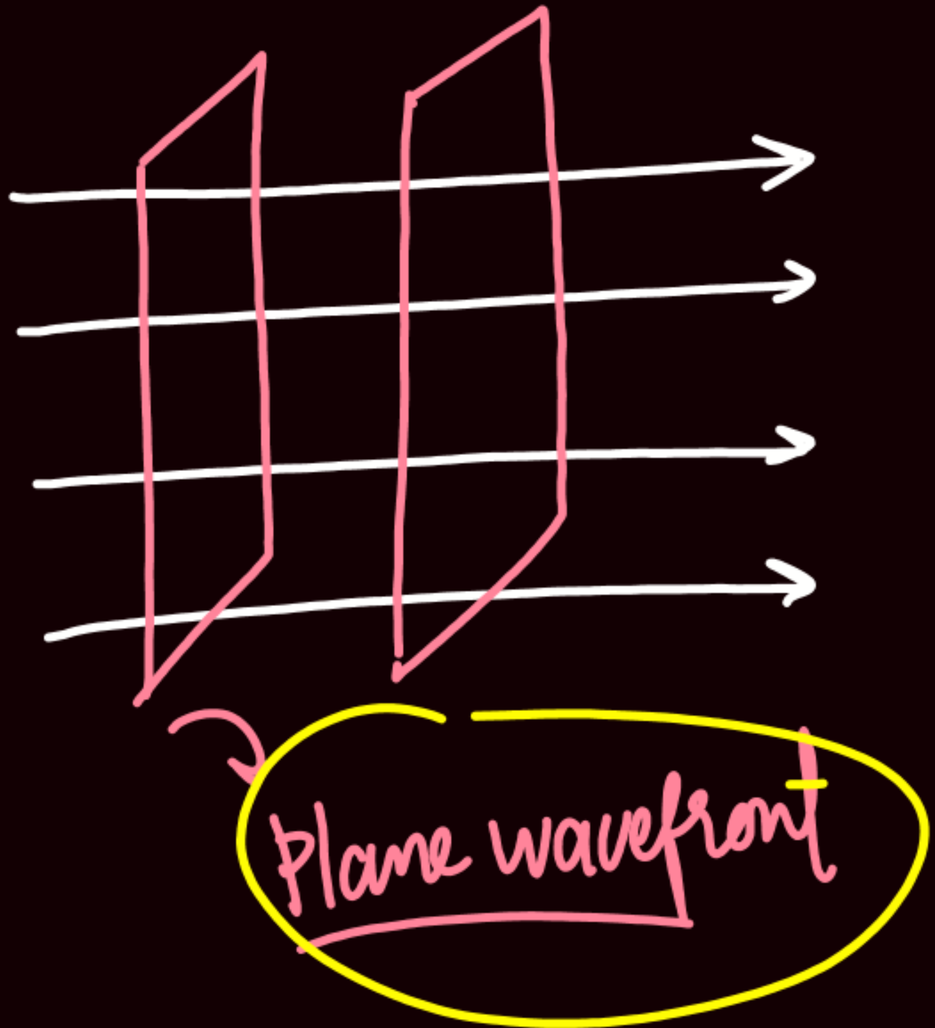
$$\Rightarrow 440\times10^{-9}\,m$$

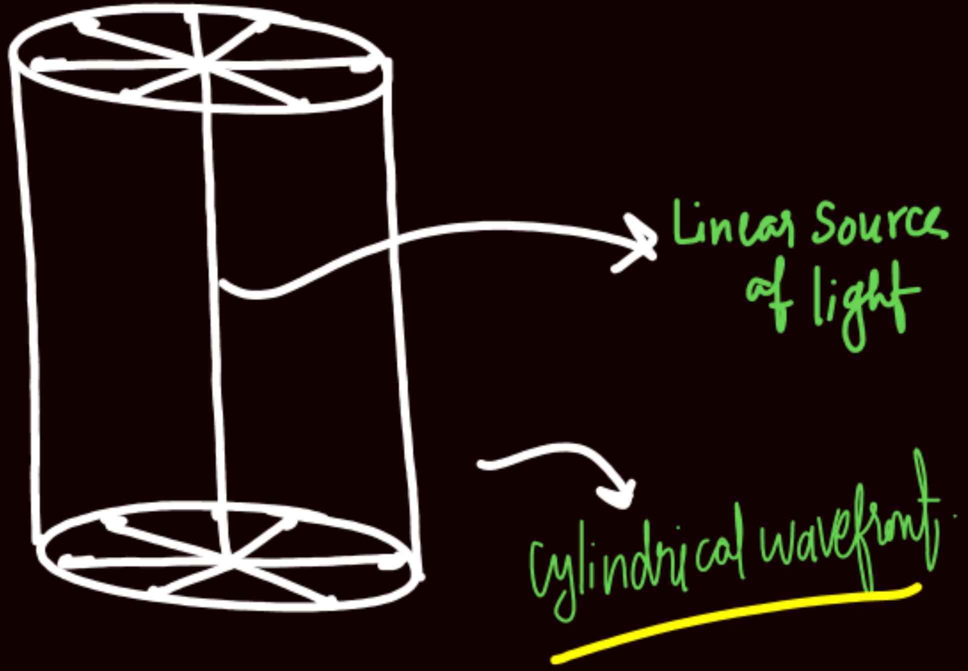
$$\Rightarrow 440\,nm.$$

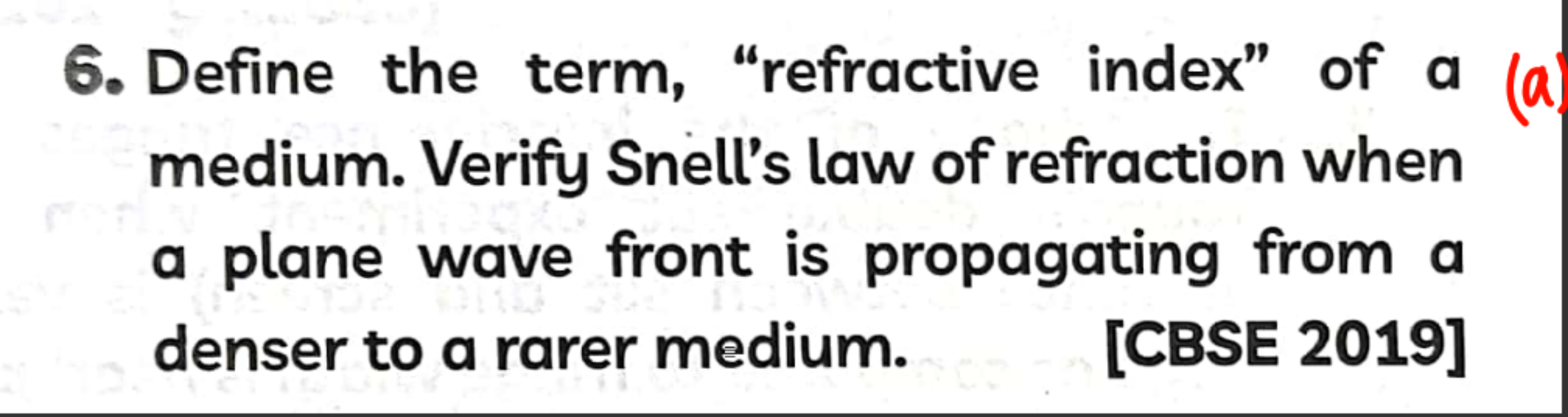
Types of wave front

- **Spherical Wave front** → **Point source**
- **Plane wave front** → **Source at infinity**
- **Cylindrical wavefront** → **Thin rectangular strip / linear source**





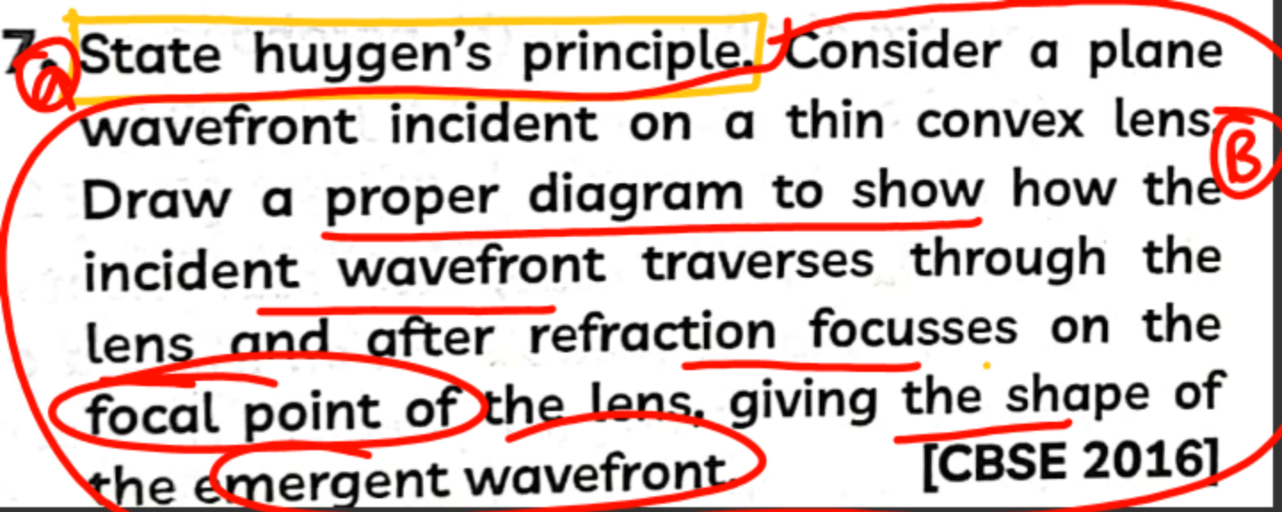




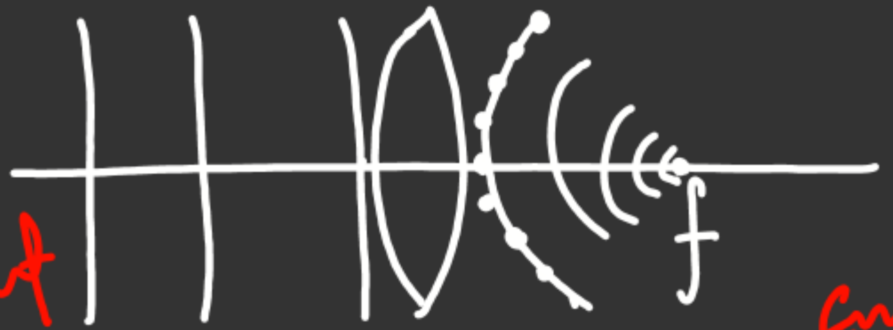
6. Define the term, "refractive index" of a medium. Verify Snell's law of refraction when a plane wave front is propagating from a denser to a rarer medium. [CBSE 2019]

(a) Refractive index is the ratio of velocity of light in vacuum to the velocity of light in medium.

$$\mu = \frac{V_{vacuum}}{V_{medium}}$$



7. Ⓐ State huygen's principle. Consider a plane wavefront incident on a thin convex lens. Ⓑ Draw a proper diagram to show how the incident wavefront traverses through the lens and after refraction focusses on the focal point of the lens, giving the shape of the emergent wavefront. [CBSE 2016]



Incident w.f = plane

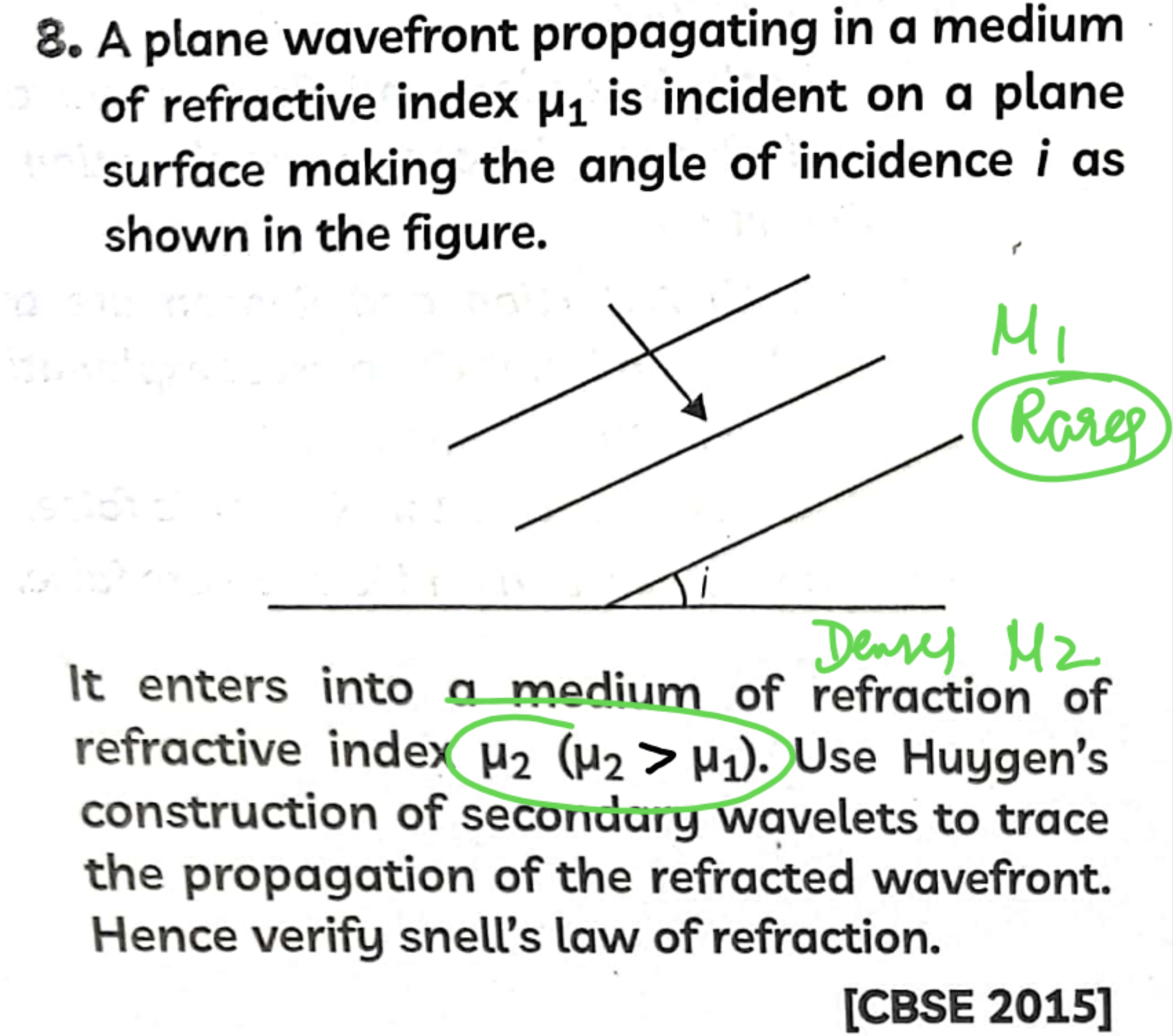
Emergent w.f = Spherical

Huygen's Secondary wavelet Theory (Most Important)

1. Every point on a given wavefront act as fresh source of disturbance and forms its own wave called secondary wavelet or wavelet.

2. In homogenous medium secondary wavelet spread with same speed in all direction.

3. Tangent drawn in forward direction on secondary wavelet gives a new wavefront.

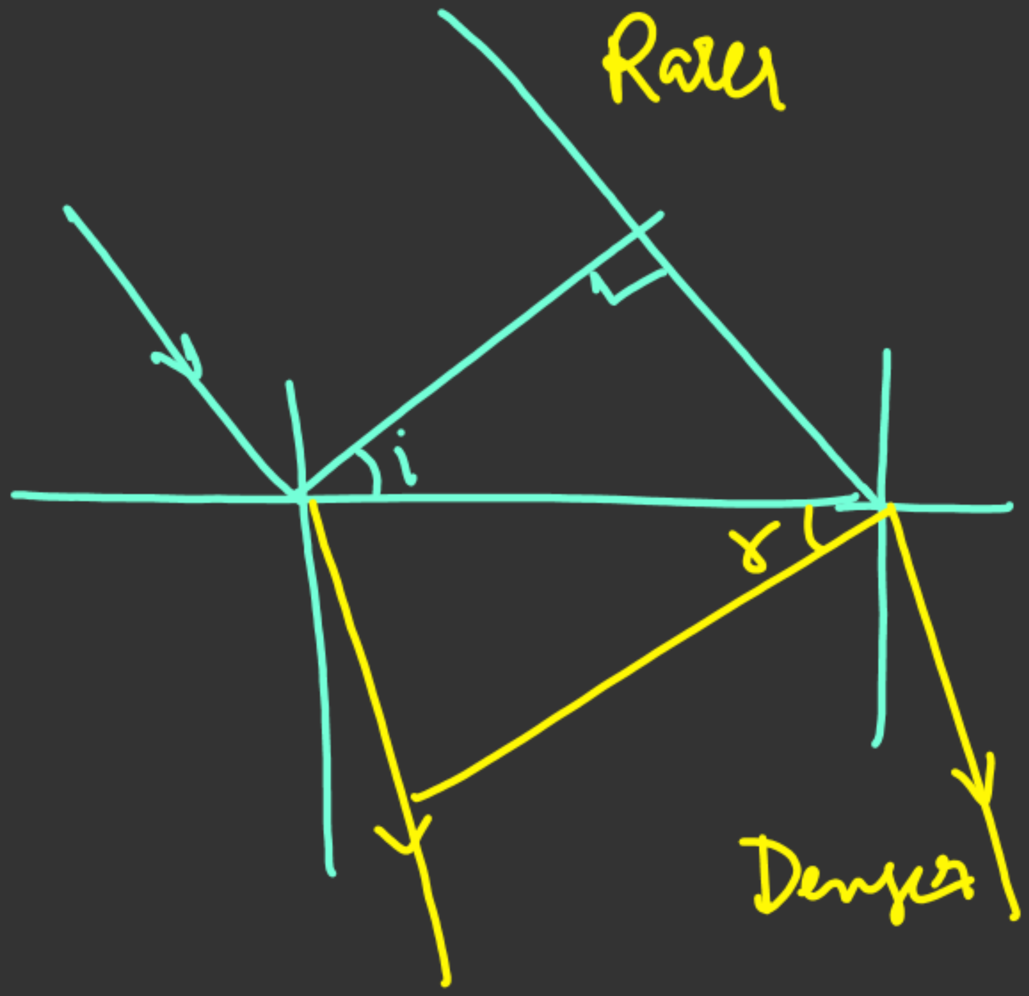


8. A plane wavefront propagating in a medium of refractive index μ_1 is incident on a plane surface making the angle of incidence *i* as shown in the figure.

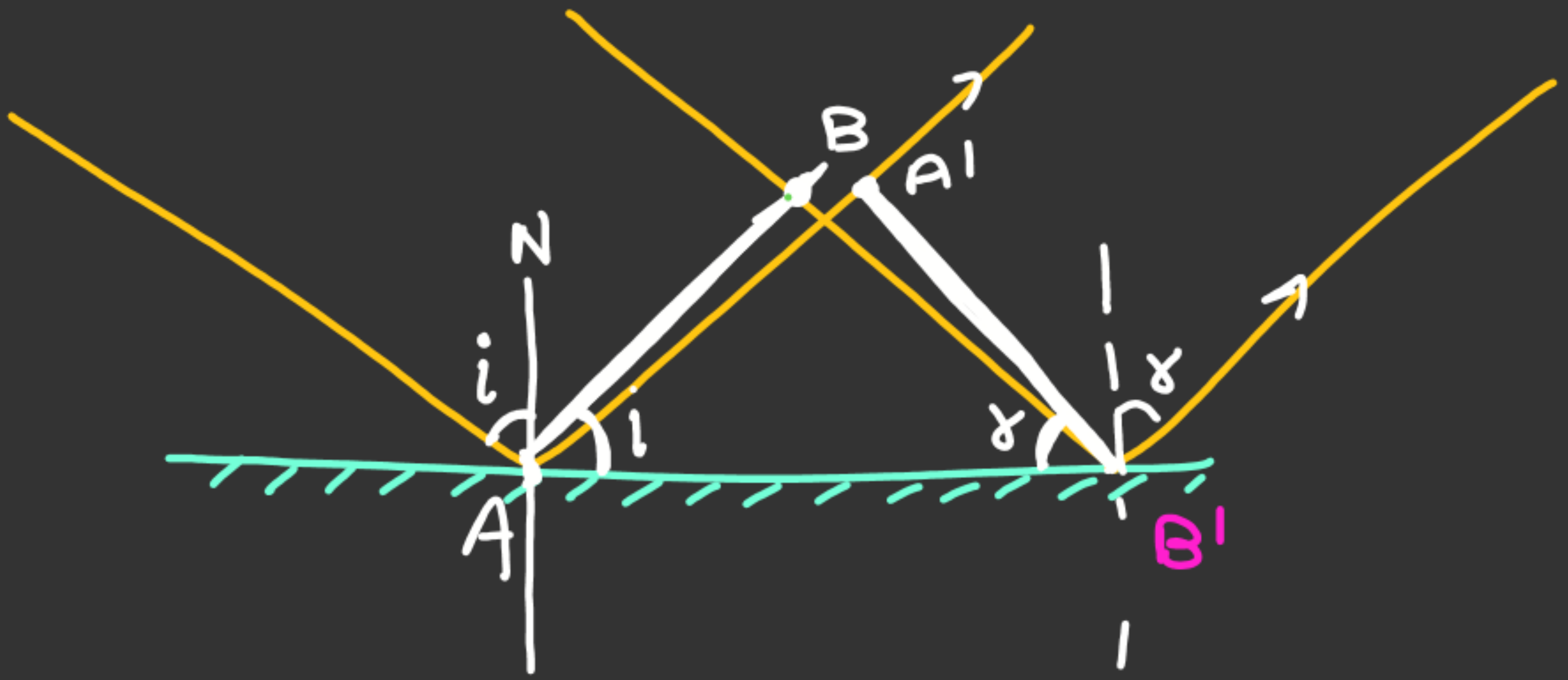
i
M1
Rarer
Denser M2

It enters into a medium of refraction of refractive index μ_2 ($\mu_2 > \mu_1$). Use Huygen's construction of secondary wavelets to trace the propagation of the refracted wavefront. Hence verify snell's law of refraction.

[CBSE 2015]



Law of Reflection using huygen's wave theory



In ABB'

$$\sin i = \frac{BB'}{AB'}$$

In AA'B'

$$\sin r = \frac{AA'}{AB'}$$

$$\frac{\sin i}{\sin r} = \frac{BB'}{\cancel{AB'}} \times \frac{\cancel{AB'}}{AA'}$$

$$\frac{\sin i}{\sin r} = \frac{BB'}{AA'}$$

$$\frac{\sin i}{\sin r} = \frac{\cancel{ct}}{\cancel{ct}}$$

$$\frac{\sin i}{\sin r} = 1$$

$$\sin i = \sin r$$

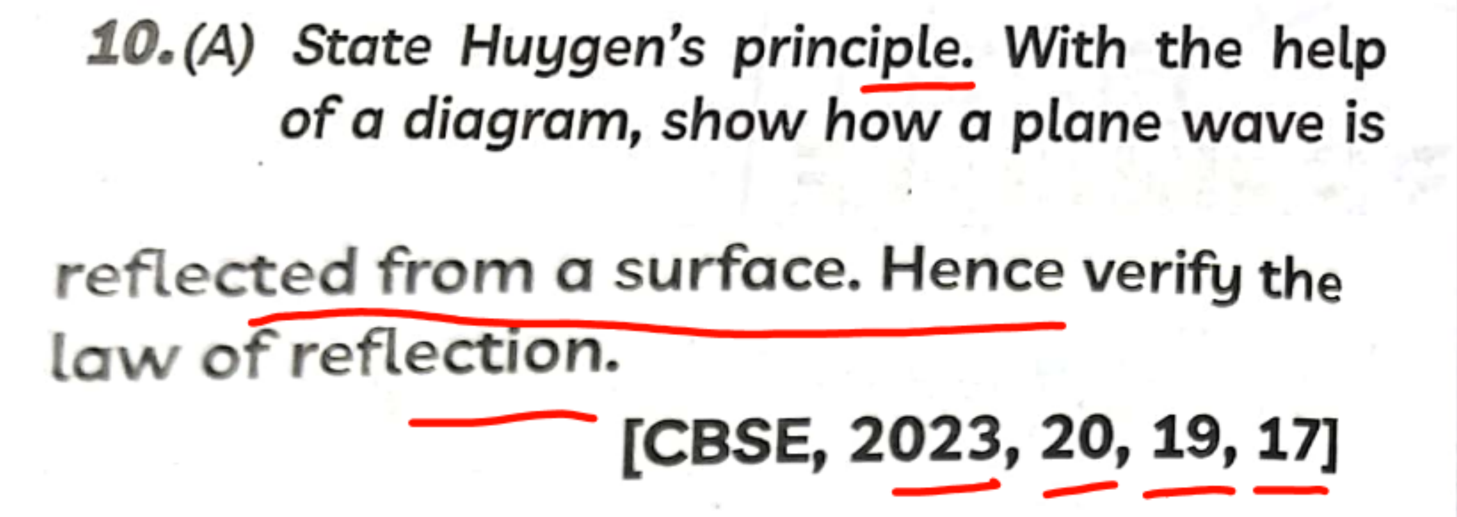
for very small,

$$\boxed{i = r} \; //$$

This proves law of Reflection using huygen wave theory.

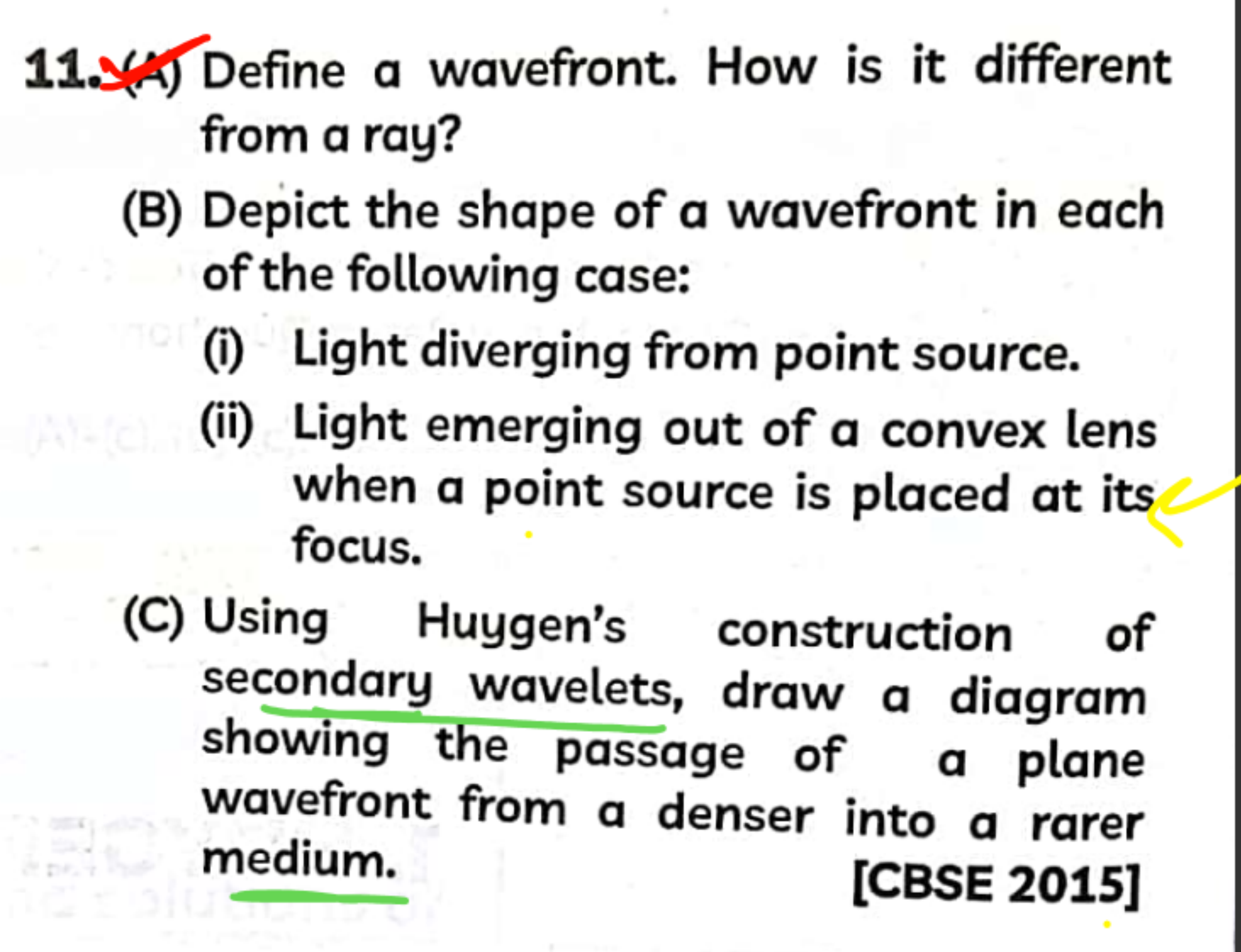
9. Define the term ‘coherent sources’ which are required to produce interference pattern in Young’s double slit experiment.

[CBSE 2014]



10. *(A) State Huygen's principle. With the help of a diagram, show how a plane wave is* reflected from a surface. Hence verify the law of reflection.

[CBSE, 2023, 20, 19, 17]



11. ~~(A)~~ Define a wavefront. How is it different from a ray?

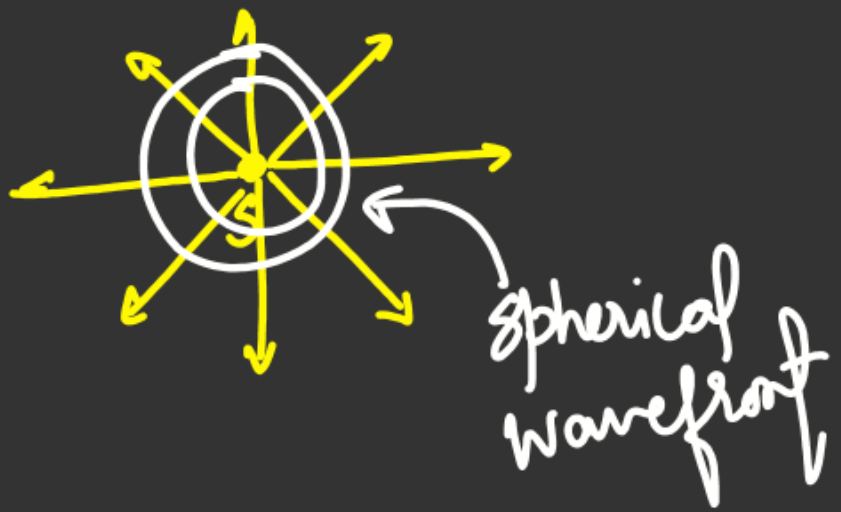
(B) Depict the shape of a wavefront in each of the following case:

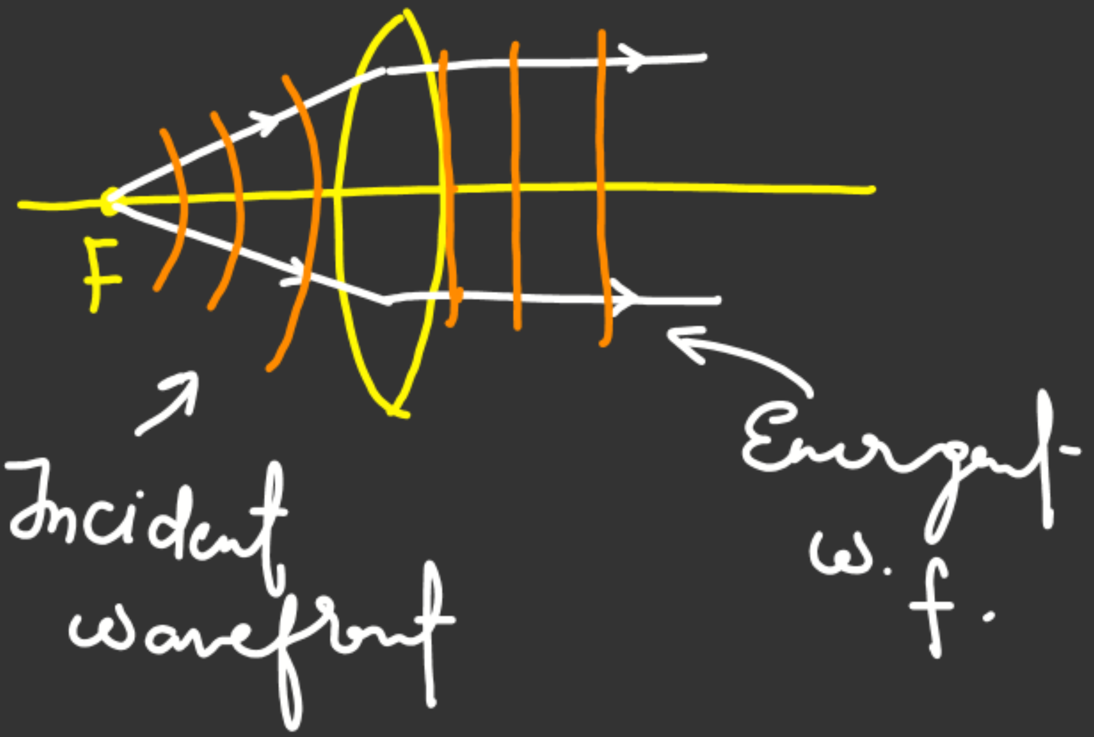
(i) Light diverging from point source.

(ii) Light emerging out of a convex lens when a point source is placed at its focus.

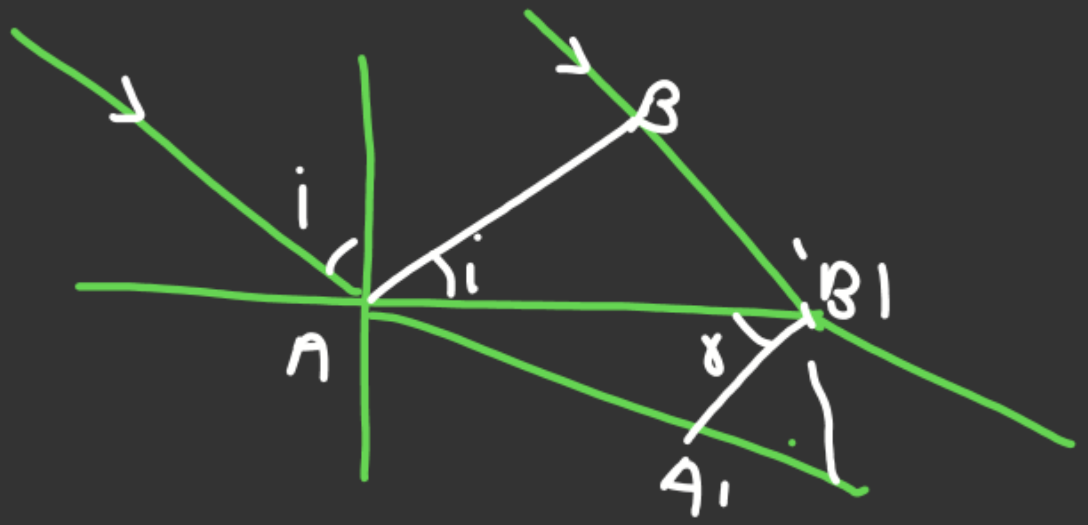
(C) Using Huygen's construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser into a rarer medium. [CBSE 2015]

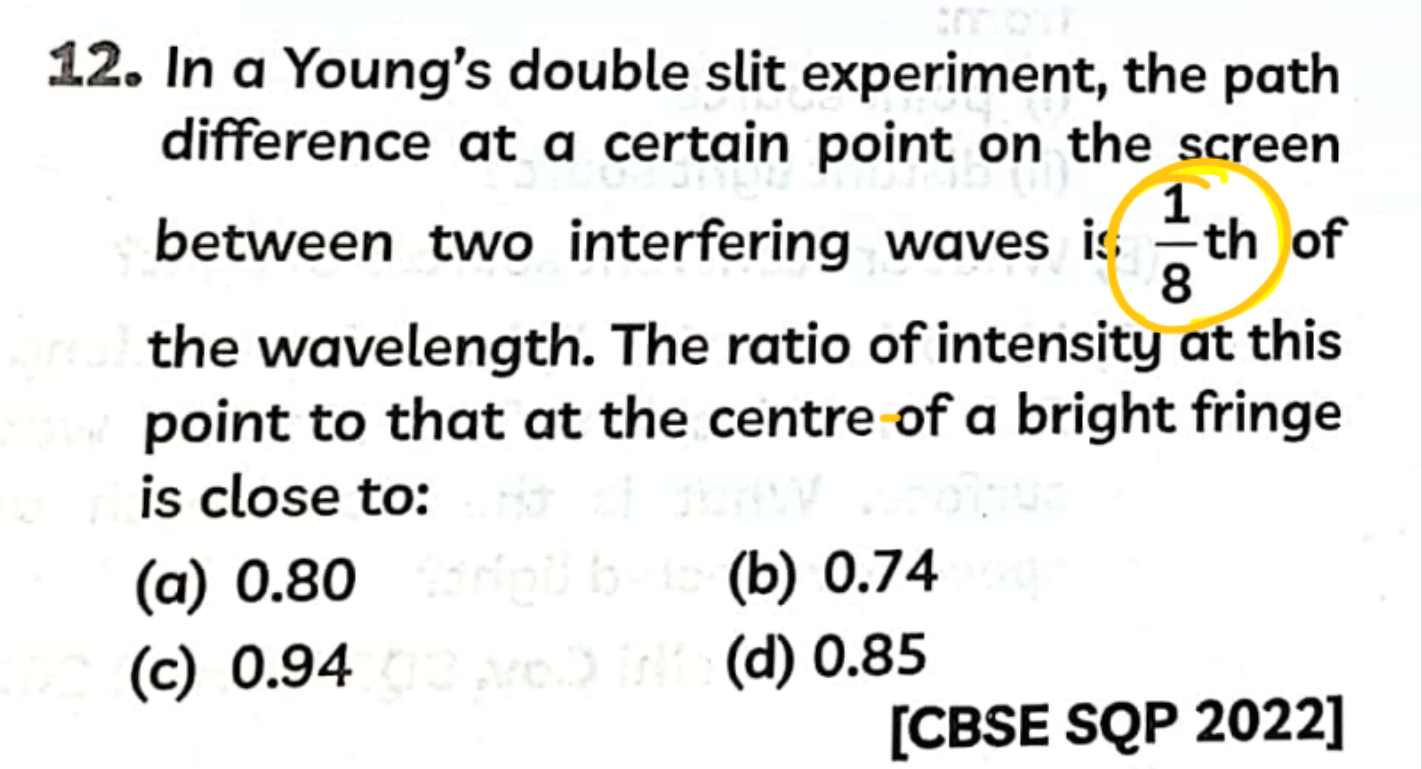
B - (i)





(C)





12. In a Young's double slit experiment, the path difference at a certain point on the screen between two interfering waves is $\frac{1}{8}$th of the wavelength. The ratio of intensity at this point to that at the centre of a bright fringe is close to:

(a) 0.80 (b) 0.74

(c) 0.94 (d) 0.85

[CBSE SQP 2022]

$$\Delta x = \frac{1}{8}\lambda$$

$$I = I_{max}\cos^2\left(\frac{\Delta\phi}{2}\right)$$

$$I = I_{max}\cdot\cos^2\left(\frac{\frac{2\pi}{\lambda}\cdot\Delta x}{2}\right)$$

$$I = I_{max}\cdot\cos^2\left(\frac{\frac{\cancel{2}\pi}{\cancel{\lambda}}\cdot\frac{\cancel{\lambda}}{8}}{\cancel{2}}\right)$$

$\cos\left(\frac{\pi}{8}\right)$

$\cos(22.5)$

$\cos 0 - 1$

$\cos 22.5 - 0.92$

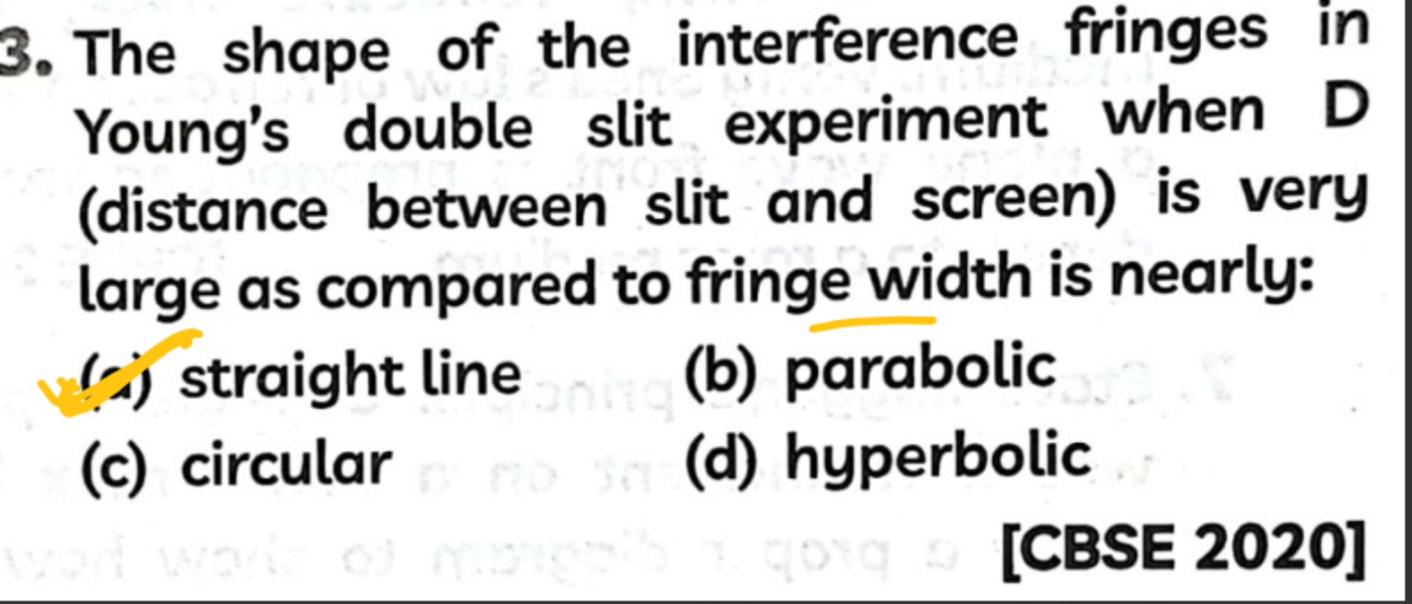
$\cos 30 = 0.86.$

$$I = I_{max}\cdot\cos^2\left(\frac{\pi}{8}\right)$$

$$I = I_{max}\,(0.92)^2$$

$$I = I_{max}\cdot 0.85$$

$$\boxed{\frac{I}{I_{max}} = 0.85}$$

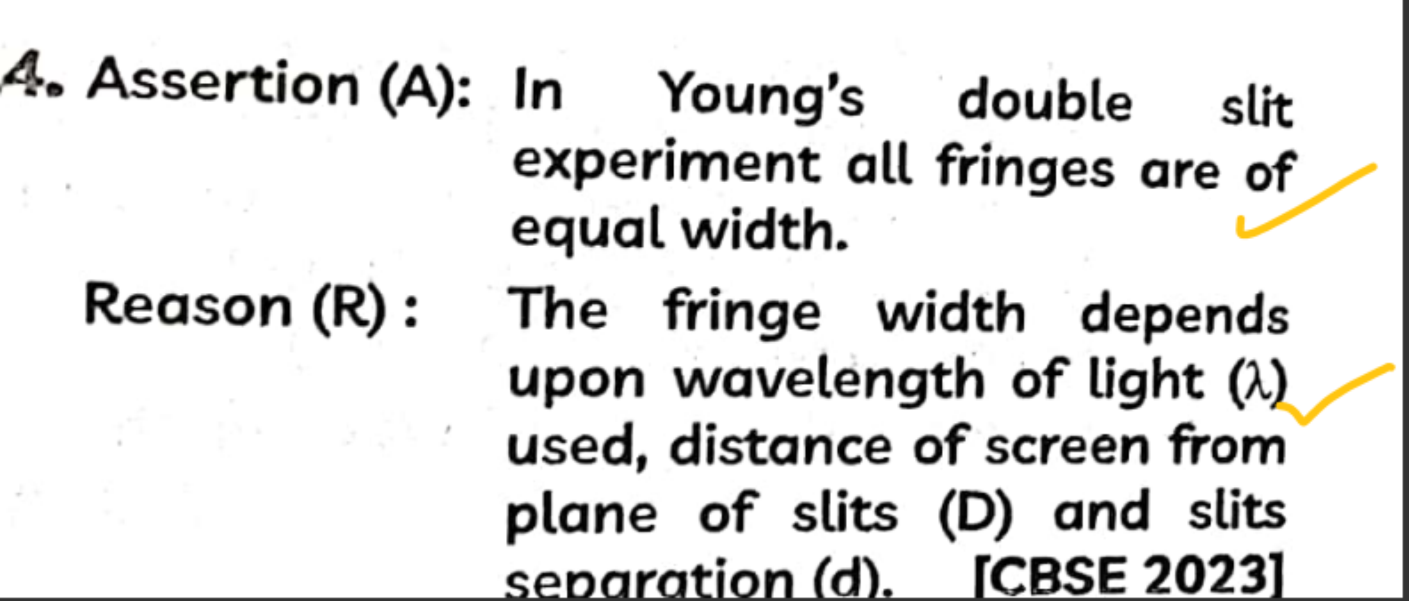


3. The shape of the interference fringes in Young's double slit experiment when D (distance between slit and screen) is very large as compared to fringe width is nearly:

[✓ (a) straight line] (b) parabolic

(c) circular (d) hyperbolic

[CBSE 2020]

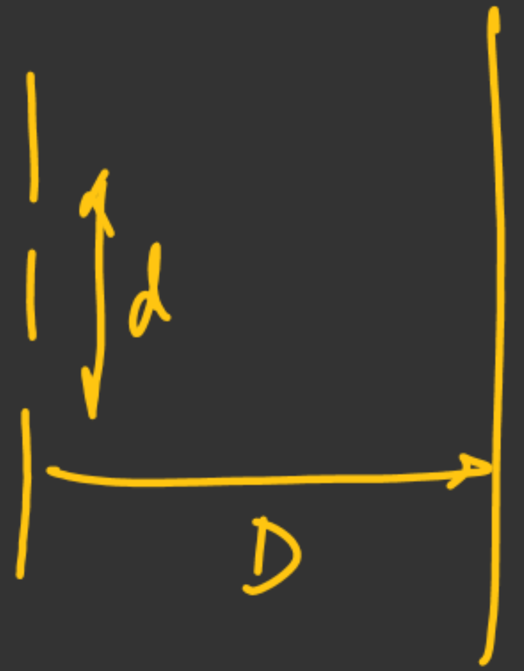


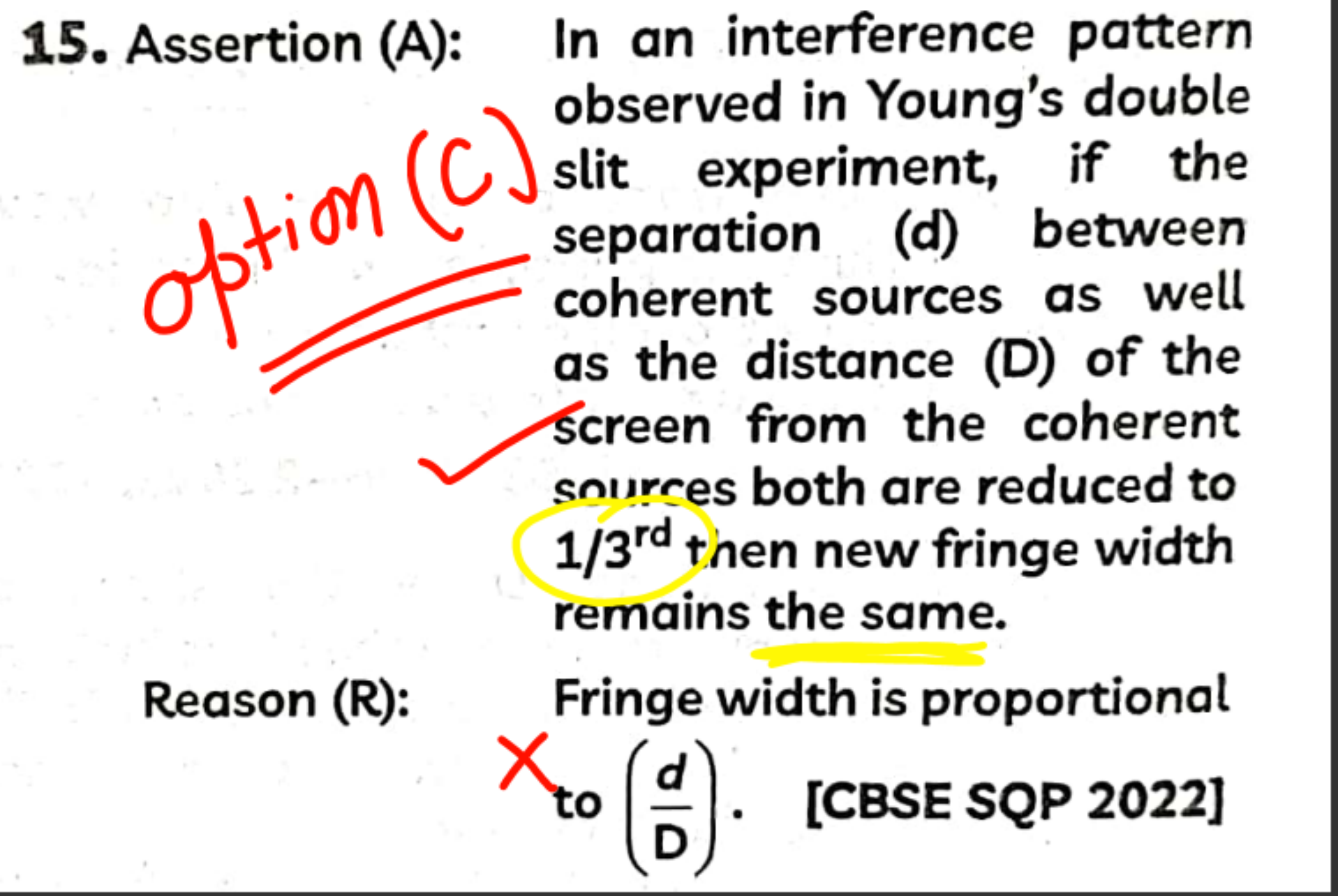
4. **Assertion (A):** In Young's double slit experiment all fringes are of equal width.

Reason (R) : The fringe width depends upon wavelength of light (λ) used, distance of screen from plane of slits (D) and slits separation (d). [CBSE 2023]

$\hookrightarrow$ $\underline{\underline{\text{option}}}$ (a)

$$\beta = \frac{\lambda D}{d}$$





15. Assertion (A): In an interference pattern observed in Young's double slit experiment, if the separation (d) between coherent sources as well as the distance (D) of the screen from the coherent sources both are reduced to $1/3^{rd}$ then new fringe width remains the same. ✓

option (C)

Reason (R): Fringe width is proportional ✗ to $\left(\frac{d}{D}\right)$. [CBSE SQP 2022]

$$D = \frac{D}{3}$$

$$d = \frac{d}{3}.$$

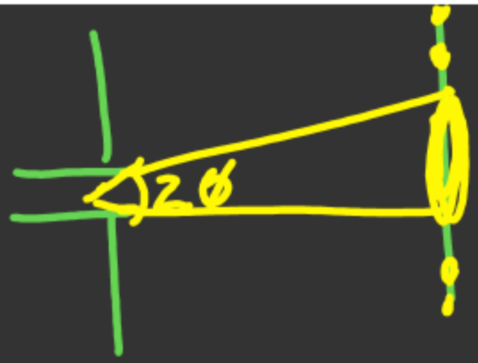
$$\beta' = \frac{\lambda D'}{d'}$$

$$\beta = \lambda \frac{D}{\cancel{3}} \cdot \frac{\cancel{3}}{d}$$

$$\beta = \frac{\lambda D}{d}$$

16. A narrow slit is illuminated by a parallel beam of monochromatic light of wavelength λ equal to 6000 Å and the angular width of the central maximum in the resulting diffraction pattern is measured. When the slit is next illuminated by light of wavelength λ', the angular width decreases by 30%. Calculate the value of the wavelength λ'.

[CBSE SQP 2022]



$2\phi = \frac{2\lambda}{d}$

$\lambda = 6000 A°$

$\lambda' = ?$

$2\phi' = 0.7\times 2\phi$

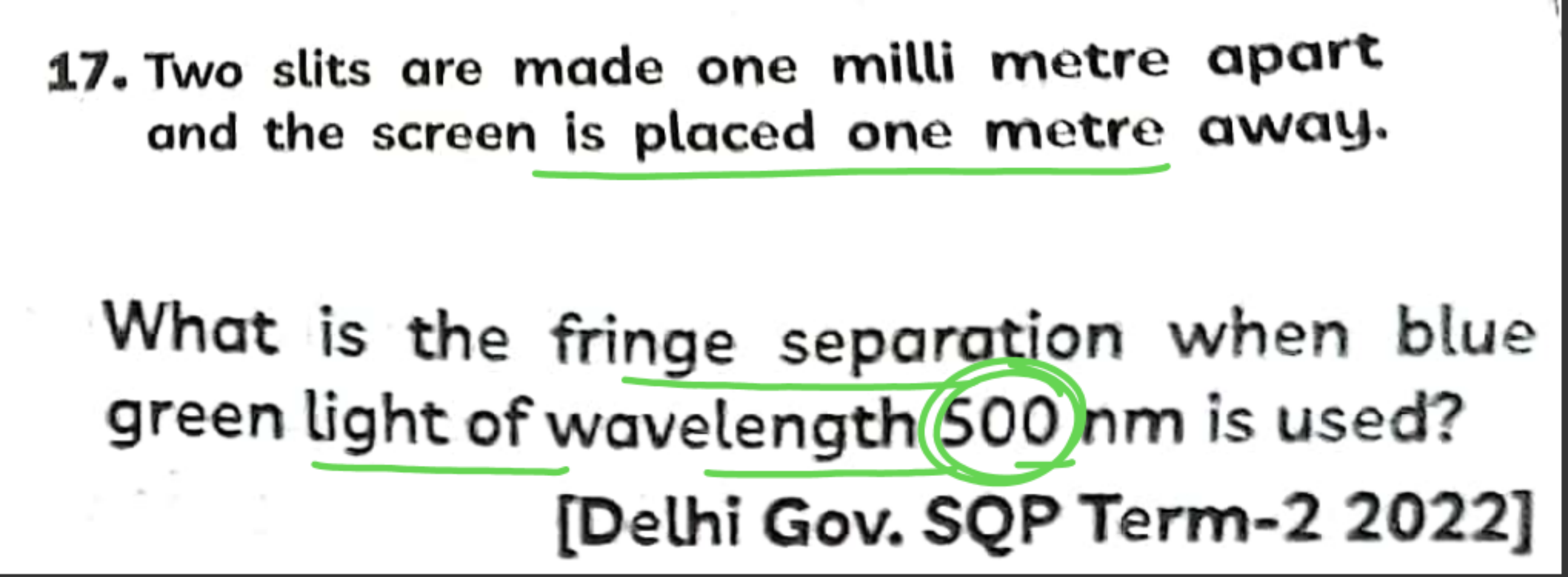
$2\phi' = 0.7\,(2\phi)$

$\cancel{2}\cdot\frac{\lambda'}{\cancel{d}} = 0.7\times\cancel{2}\cdot\frac{\lambda}{\cancel{d}}$

$\lambda' = 0.7\times\lambda$

$\lambda' = 0.7\times 6000 A°$

$\boxed{\lambda' = 4200 A°}$



17. Two slits are made one milli metre apart and the screen is placed one metre away.

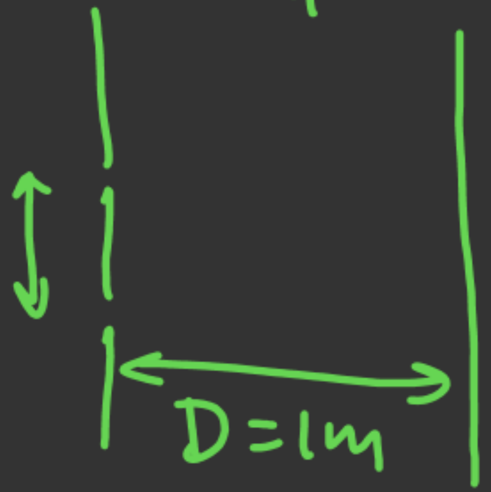
What is the fringe separation when blue green light of wavelength 500 nm is used?

[Delhi Gov. SQP Term-2 2022]

$$\boxed{\lambda' = \frac{\lambda}{\mu}}$$

$$\boxed{\beta' = \frac{\beta}{\mu}}$$

$d = 1\times10^{-3}\,m$



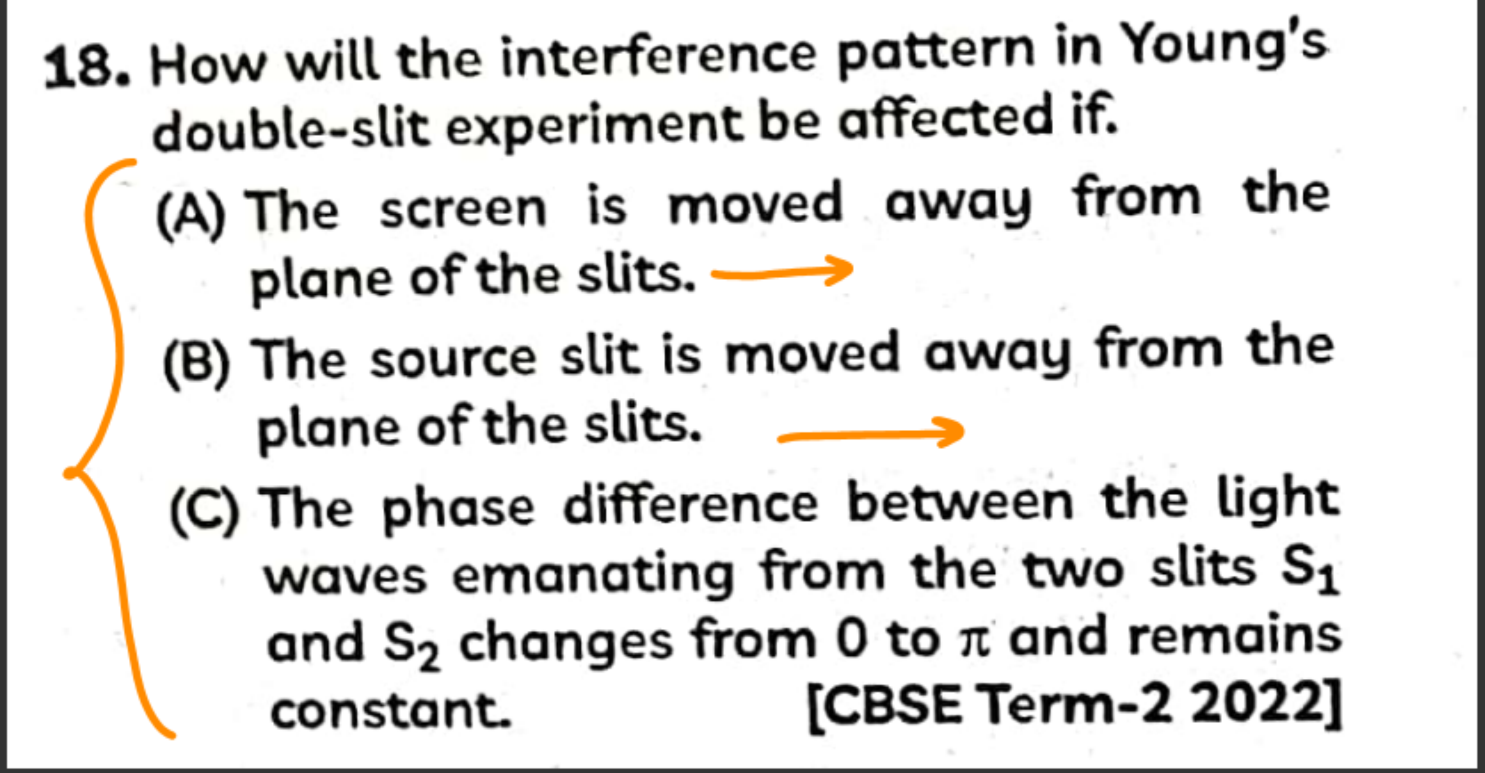
$D = 1m$

$\lambda = 500\times10^{-9}\,m$

$$\beta = \frac{\lambda D}{d}$$

$$\beta = \frac{500\times\cancel{10^{-9}}\times1}{\cancel{10^{-3}}}\ 10^{-6}$$

$$\beta = 0.5\times10^{-3}\,m \longrightarrow \boxed{\beta = 0.5\,mm}$$



18. How will the interference pattern in Young's double-slit experiment be affected if.

(A) The screen is moved away from the plane of the slits.

(B) The source slit is moved away from the plane of the slits.

(C) The phase difference between the light waves emanating from the two slits S_1 and S_2 changes from 0 to π and remains constant. [CBSE Term-2 2022]

(a) $D \uparrow$, $\beta \propto D$, fringe width will also increase.

(b) Intensity of fringe will reduce and it will become less sharp.

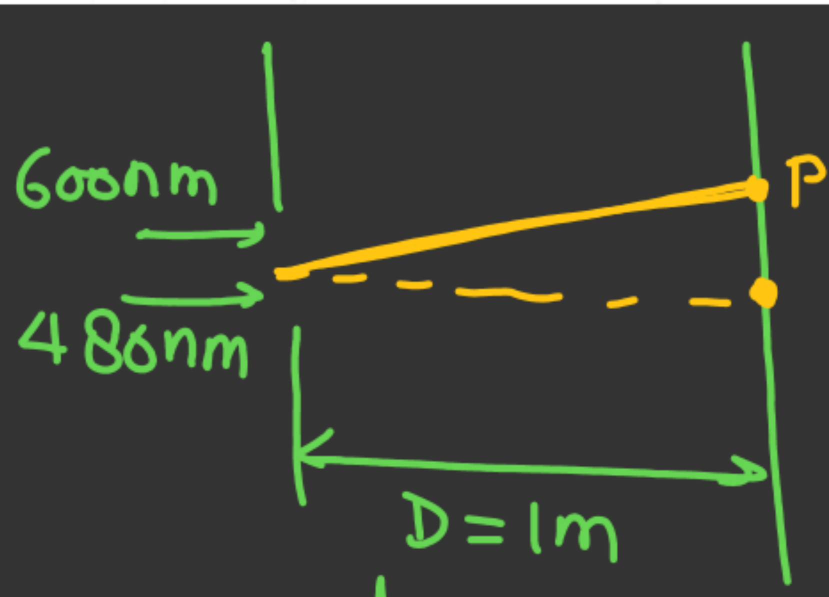
(c) If phase. diff b/w two interfering waves will become π (odd) so. Central fringe will be Dark.

A slit of width 0.6 mm is illuminated by a beam of light consisting of two wavelengths 600 nm and 480 nm. The diffraction pattern is observed on a screen 1.0 m from the slit. Find:

(A) The distance of the second bright fringe from the central maximum pertaining to light of 600 nm.

(B) The least distance from the central maximum at which bright fringes due to both the wavelengths coincide.

[CBSE Term-2 2022]



d=0.6mm

$$x = \boxed{\frac{n\lambda D}{d}}$$

$$x = \frac{2\times \overset{1000}{\cancel{600}}\times \cancel{10^{-9}}\times 1}{0.\cancel{6}\times \cancel{10^{-3}}}\ 10^{-6}$$

$$x = 2\times 10^{-3}\ m$$

$$\boxed{x = 2mm}$$

(B) let at point P, n fringes of 480nm and (n-1) fringes of 600nm are formed

So.

$$(n-1)\lambda_{600} = n\lambda_{480}$$

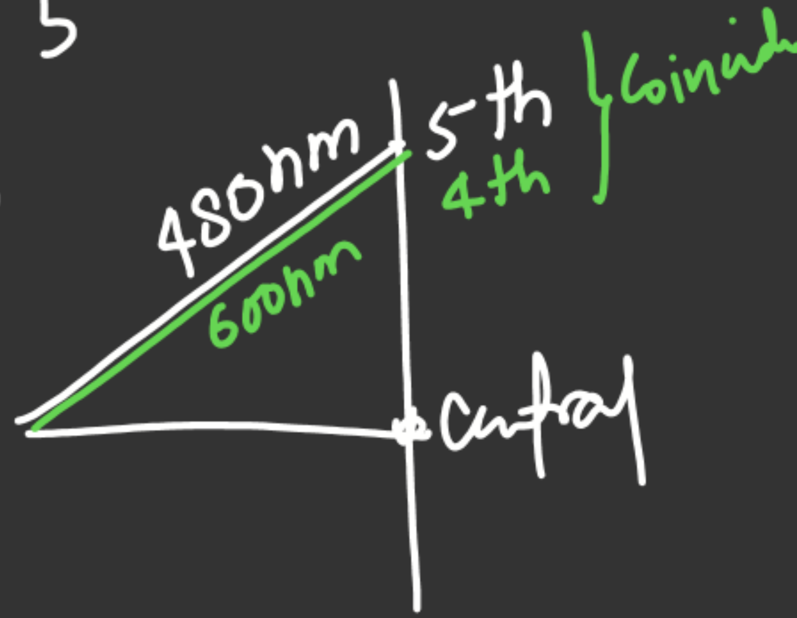
$$(n-1)\overset{}{\cancel{600}}_{5} = n(\cancel{480})_{4}$$

$$5n-5 = 4n$$

$$5n-4n = 5$$

$$\boxed{n=5}$$

Least distance =



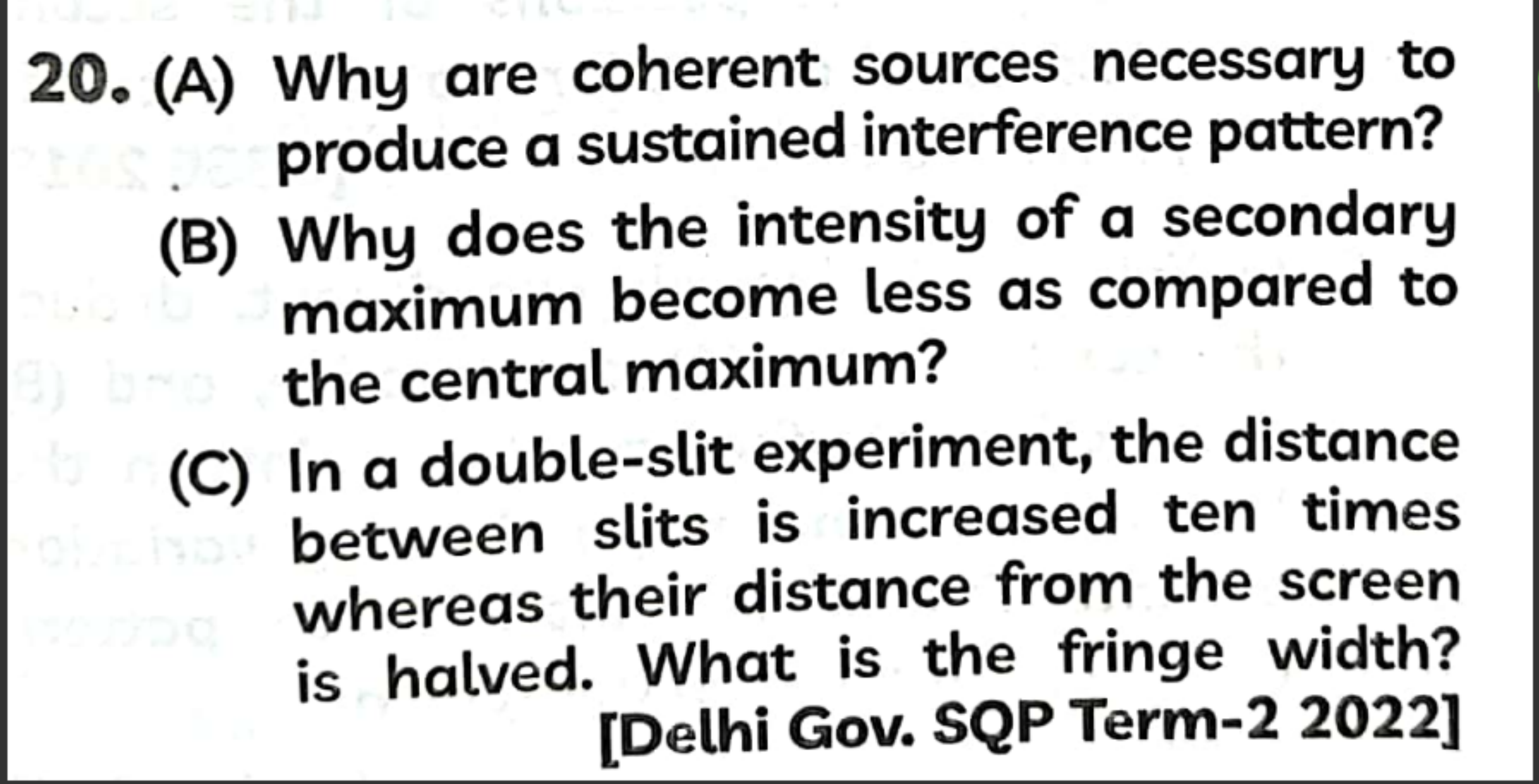
least distance $x' = n\frac{\lambda D}{d}$

$$x' = \frac{5(\overset{800}{\cancel{480}}\times\cancel{10^{-9}})}{\cancel{0.6}\times\cancel{10^{-3}}}\,10^{-6}$$

$$x' = 4000\times10^{-6}$$

$$x' = 4\times10^{-3}\,m$$

$$\boxed{x' = 4mm}$$



20. (A) Why are coherent sources necessary to produce a sustained interference pattern?

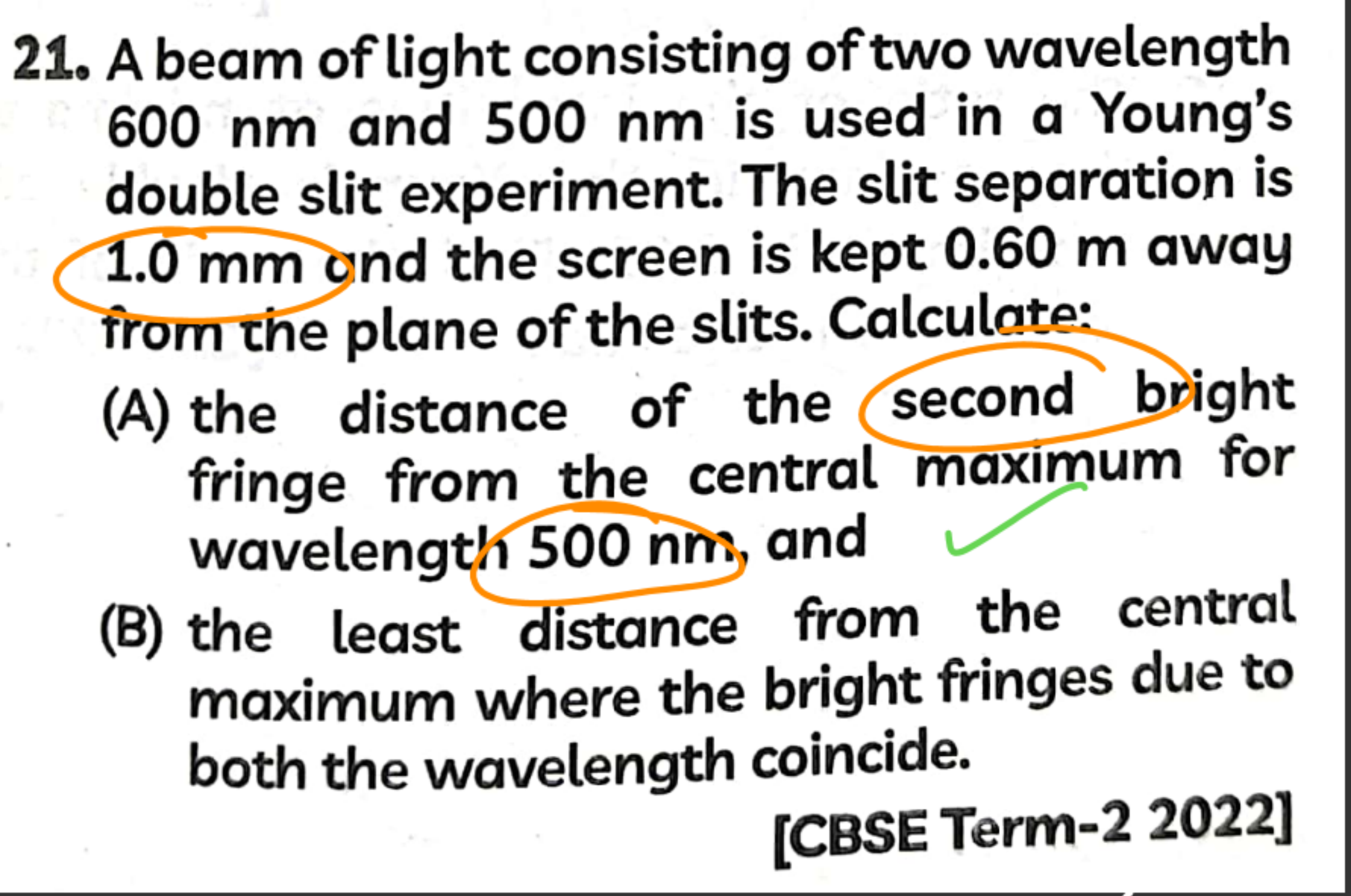
(B) Why does the intensity of a secondary maximum become less as compared to the central maximum?

(C) In a double-slit experiment, the distance between slits is increased ten times whereas their distance from the screen is halved. What is the fringe width?

[Delhi Gov. SQP Term-2 2022]

Ⓐ Coherent sources produce wave having constant phase difference. This ensures that position of maxima and minima does not change with time or to get sustained interference.

Ⓑ Central maxima is due to Const interference of waves from all parts of wavefront while first secondary maxima is due to Const. interference of one third part of wavefront. Hence intensity decreases.



21. A beam of light consisting of two wavelength 600 nm and 500 nm is used in a Young's double slit experiment. The slit separation is 1.0 mm and the screen is kept 0.60 m away from the plane of the slits. Calculate:

(A) the distance of the second bright fringe from the central maximum for wavelength 500 nm, and

(B) the least distance from the central maximum where the bright fringes due to both the wavelength coincide.

[CBSE Term-2 2022]

d = 1mm

D = 0.6m

(a) $x = n\frac{\lambda D}{d}$

$$x = \frac{2\times 500\times \cancelto{10^{-6}}{10^{-9}}\times 0.6}{\cancel{10^{-3}}}$$

600×10^{-6}

0.6×10^{-3}

$$\boxed{x = 0.6\,mm}$$

(B) let at point P n bright fringes of 500nm coincides with (n-1) bright fringes of 600nm wavelength

$$(n-1)6\cancel{00} = n(5\cancel{00})$$

$$6n-6 = 5n$$

$$\boxed{n=6}$$

So here 6th fringe of 500nm and 5th fringe of 600nm coincide.

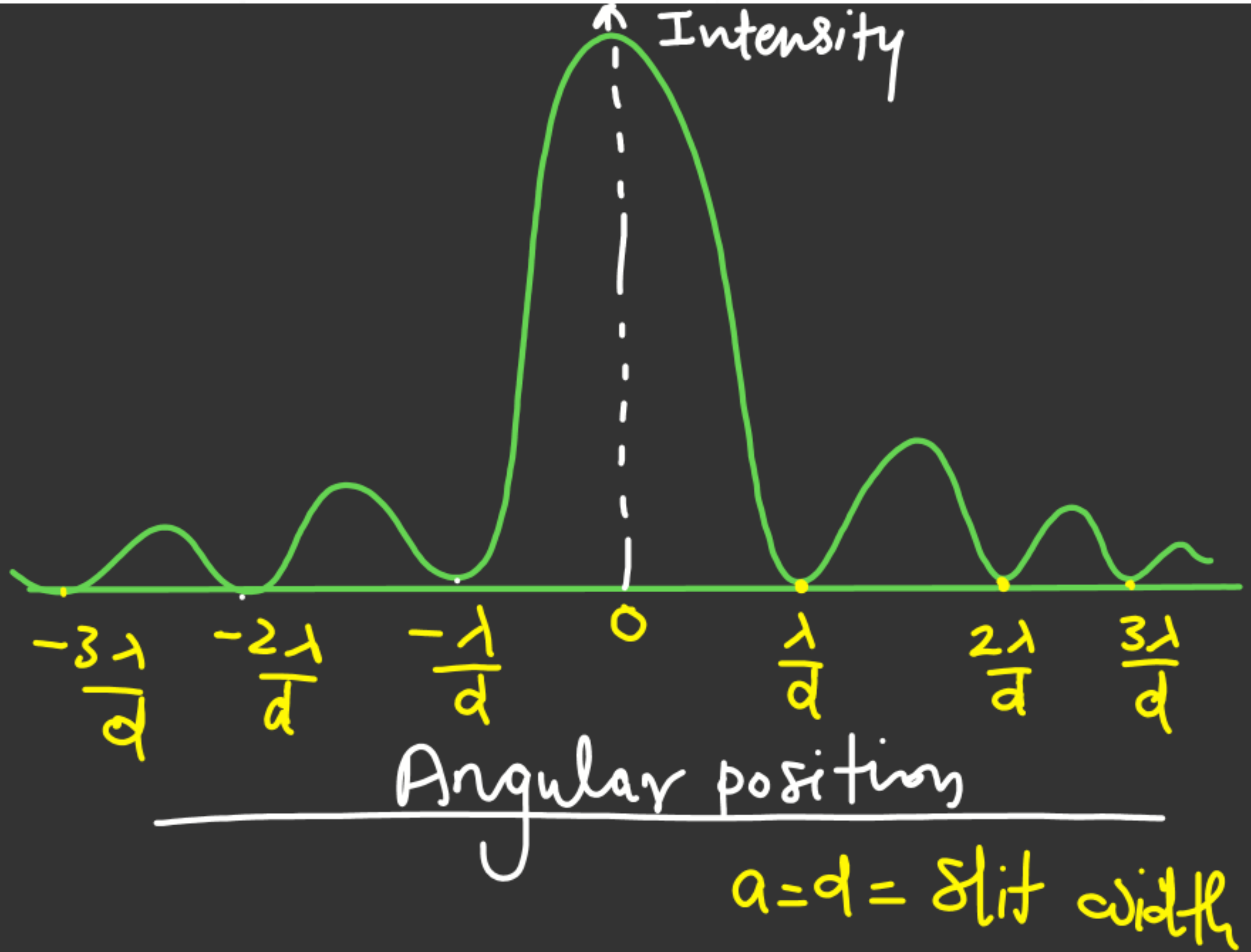
Least distance ⇒ $x' = n\frac{\lambda D}{d}$

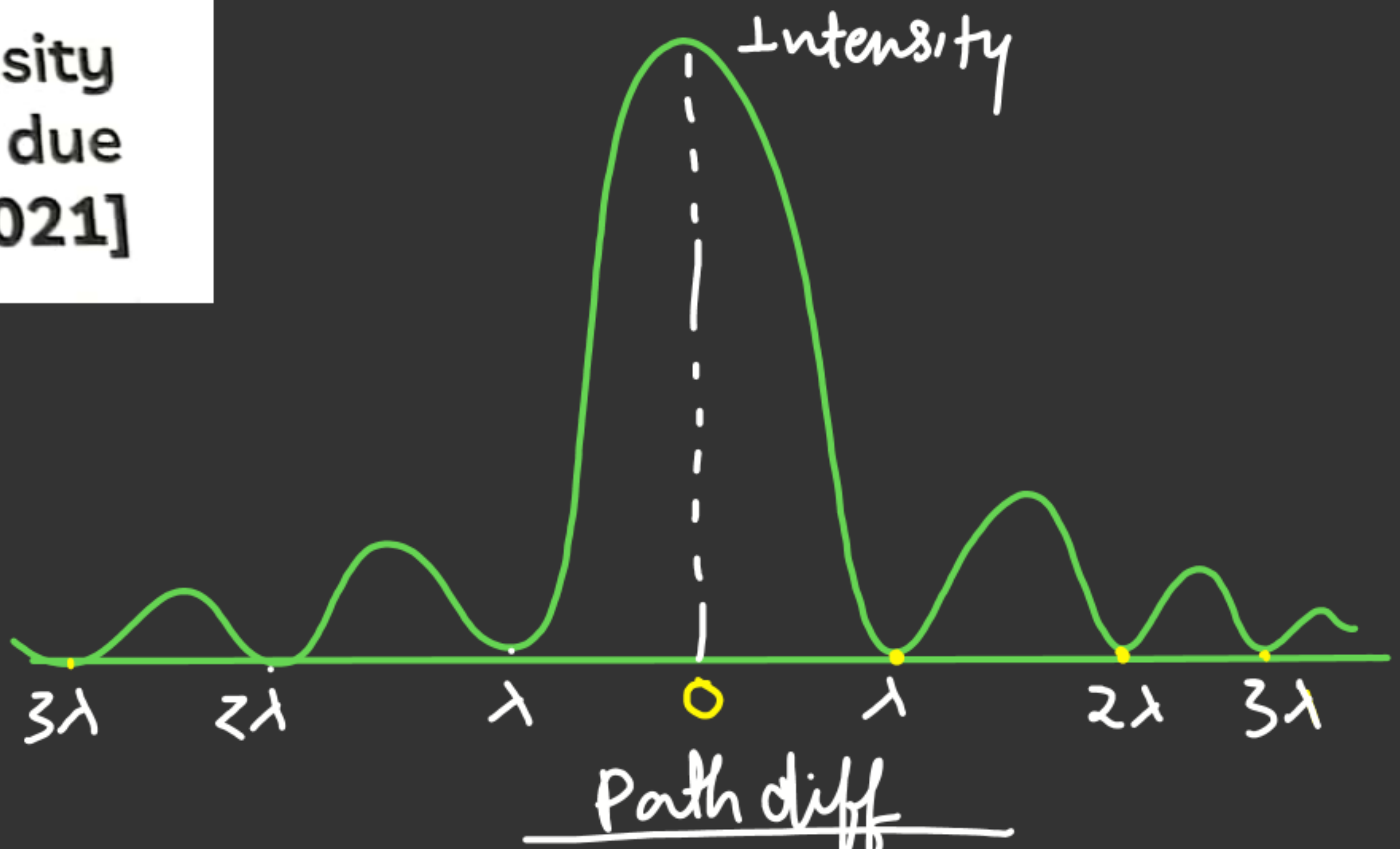
$$x' = \frac{6\times500\times\cancelto{10^{-6}}{10^{-9}}\times0.6}{\cancel{10^{-3}}}$$

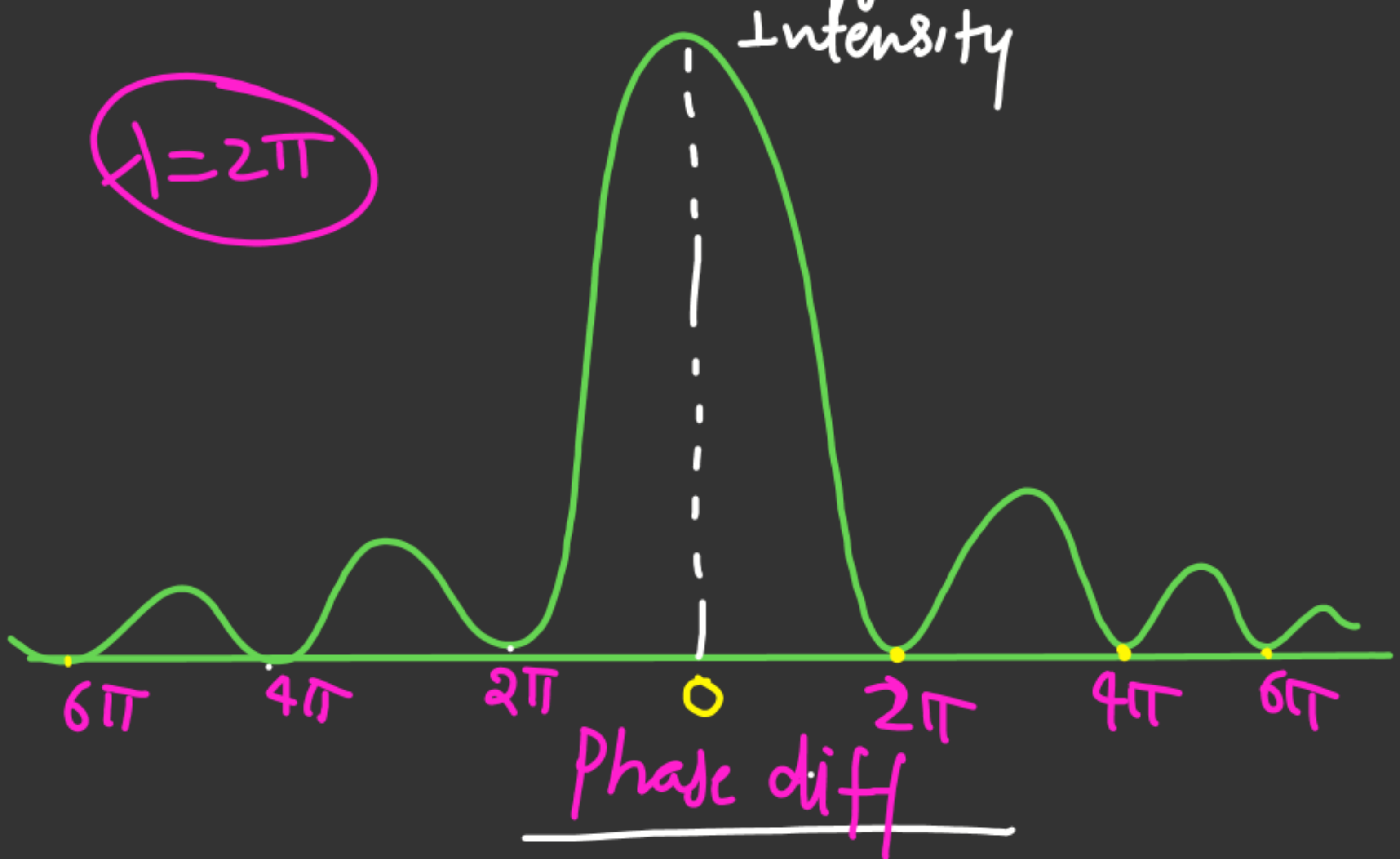
$$x' = 1800\times10^{-6}\,m$$

$$\boxed{x' = 1.8\,mm}$$

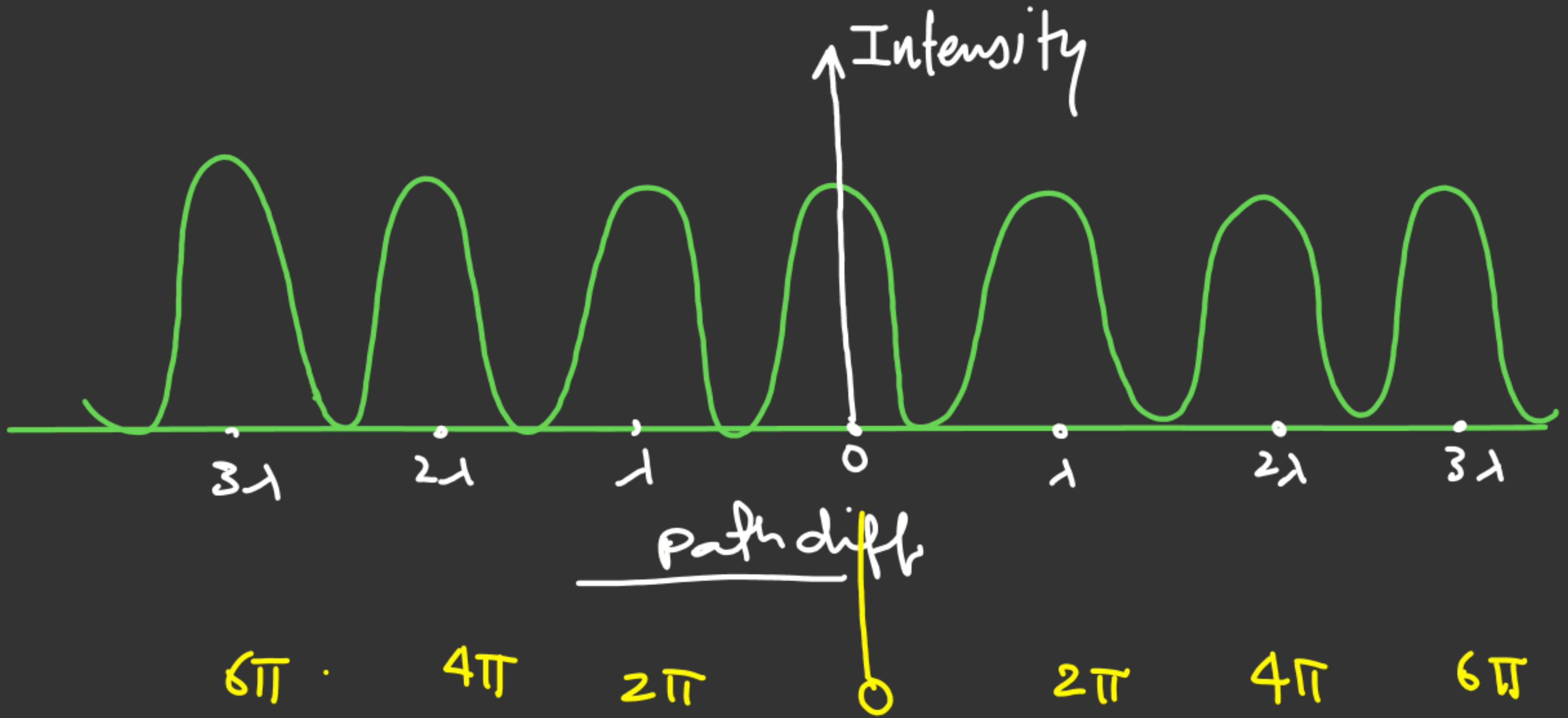
26. Draw the graph showing intensity distribution of fringes with phase angle due to diffraction through single slit.[CBSE 2021]





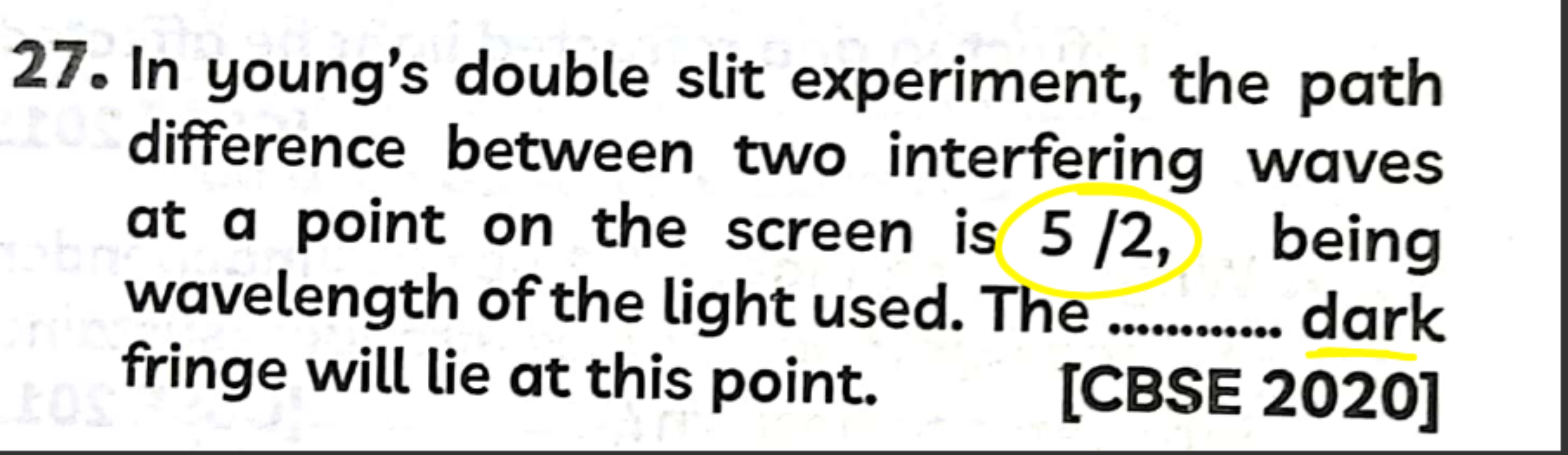


Intensity graph in double slit / YDSE / Interference in double



$n\lambda \rightarrow p$

Phase diff पूछा जाये तो π के form में लिखना है λ नहीं.



27. In young's double slit experiment, the path difference between two interfering waves at a point on the screen is 5 /2, being wavelength of the light used. The .... dark fringe will lie at this point. [CBSE 2020]

$$\Delta x = \frac{5}{2}\lambda$$

destruction

$$= (2n-1)\frac{\lambda}{2}$$

$= \quad n = 1, 2, 3.$

↓

③ → Ans

24. Two waves from two coherent sources S and S' superimpose at X as shown in figure. If X is a point on the second minima and SX - SX' is 4.5 cm. Calculate the wavelength of the waves.

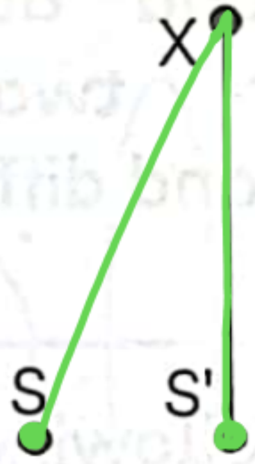
$SX - S'X = 4.5\,cm$

for minima

Path $= (2n-1)\frac{\lambda}{2}$ $(n = 1, 2, 3)$

$\boxed{n=2}$

$4.5\,cm = (2\times2-1)\frac{\lambda}{2}$



[CBSE 2021]

$\cancel{4}.5\times10^{-2} = \cancel{3}\frac{\lambda}{2}$

$1.5\times10^{-2} = \frac{\lambda}{2}$

$\boxed{\lambda = 3\times10^{-2} m}$

max.

Path $= n\lambda$

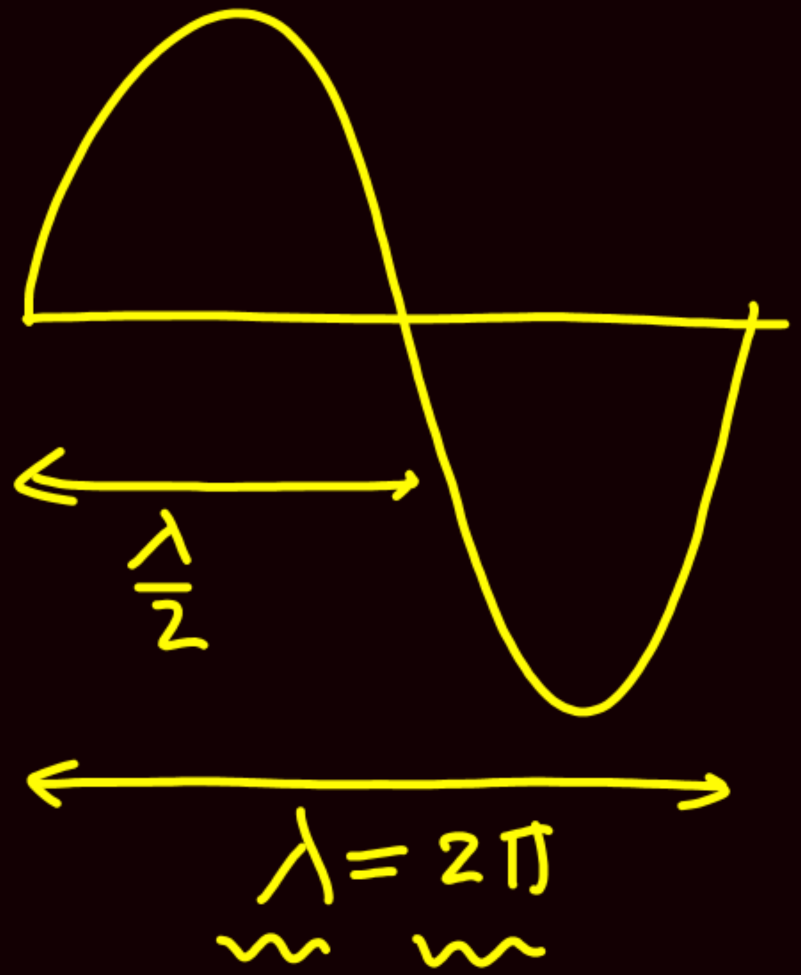
Necessary condition for constructive Interference

phase difference $0, 2\pi, \ldots\ldots 2n\pi$

path difference → $0, \lambda, 2\lambda, 3\lambda \ldots\ldots n\lambda$

here $n = 0, 1, 2, 3$

$$\begin{array}{cccc} 0, & 1, & 2, & 3 \\ \downarrow & \downarrow & \downarrow & \downarrow \\ 0 & 2\pi & 4\pi & 6\pi \end{array}$$



Necessary condition for Destructive interference

phase difference $\pi, \ 3\pi, \ 5\pi \ldots \boxed{(2n+1)\pi}$

path difference → $\frac{\lambda}{2}, \ \frac{3\lambda}{2}, \ \frac{5\lambda}{2} \ldots \boxed{(2n+1)\frac{\lambda}{2}}$

here $n = 0, 1, 2 \ldots$

Prove that Intensity of light at any point vary from 0 to 4I

Let Intensity of both sources is same so, $\boxed{I_1 = I_2 = I}$

$$I_R = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$$

$$I_R = I + I + 2I\cos\phi$$

$$I_R = 2I(1+\cos\phi) \quad ①$$

(Minimum)

for destructive interference $\boxed{\phi = \pi}$ ✓

$$I_R = 2I(1+\cos\pi)$$

$$I_R = 2I(1-1)$$

$$\boxed{I_R = 0}$$ ✓

(Max. Intensity)

for constructive interf. $\boxed{\phi = 0}$

in eq ①

$$I_R = 2I(1+\cos 0)$$

$$I_R = 2I(1+1)$$

$$I_R = 4I$$ ✓

Thus intensity varies from 0 to 4I.

Golden Points!

$$\boxed{I \propto A^2}$$

$$\boxed{I = KA^2}$$

$$\boxed{A^2 = I}$$

**

$$\boxed{A_R^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$$

$$\boxed{I_R = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi}$$

If $I_1 = I_2 = I$

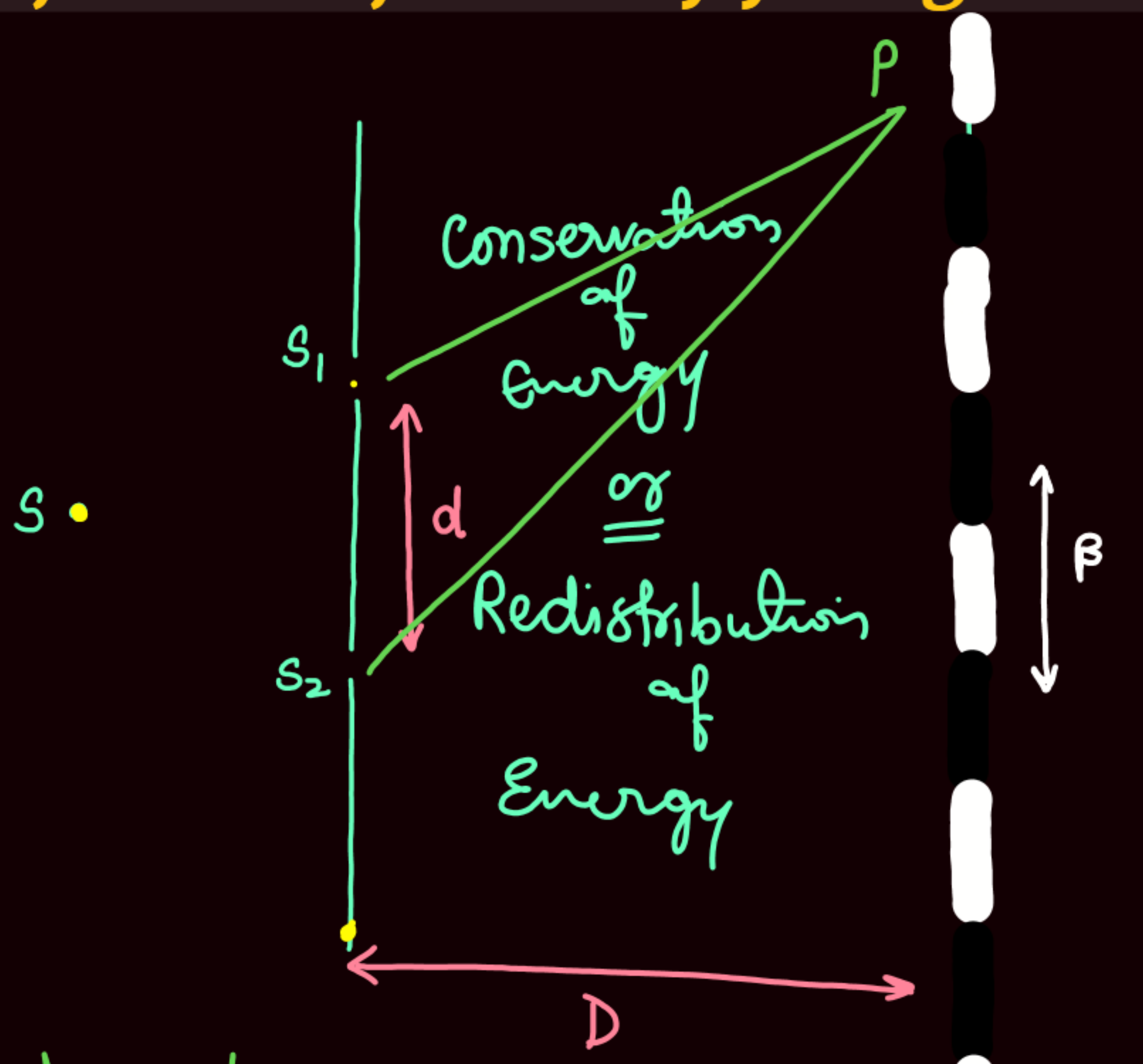
$$I_R = I + I + 2I\cos\phi$$

$$\boxed{I_R = 2I(1+\cos\phi)}$$

$$I_R = 2I \cdot 2\cos^2\frac{\phi}{2}$$

$$\boxed{I_R = 4I\cos^2\frac{\phi}{2}}$$

Interference of wave by young's Double slit experiment



Distance b/w two dark fringe = Width of Bright fringe.

fringe width $\boxed{\beta = \frac{\lambda D}{d}}$

On immersing YDSE apparatus in any medium its wavelength decreases say by μ times with respect to air.

$$\boxed{\beta' = \frac{\lambda D}{\mu d}}$$

$$\boxed{\beta' = \frac{\beta}{\mu}}$$

Width of Bright fringe = Width of Dark fringe

Necessary condition for YDSE-

- The conditions for the interference of light are as under.
  (i) In interference the source of light should be monochromatic. ✓
  (ii) Here waves should be of the same frequency. ✓
  (iii) Direction of waves should also be the same. ✓
  (iv) The amplitudes of both the waves should also be the same. ✓
  (v) The slits of both the sources should be thin.

Coherent Sources

- Coherent source of light are those sources which emit a light wave having the same frequency, wavelength and in the same phase or they have a constant phase difference

* $$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} \Rightarrow \frac{\cancel{a_2}}{\cancel{a_2}}\,\frac{\left(\frac{a_1}{a_2}+1\right)^2}{\left(\frac{a_1}{a_2}-1\right)^2} \Rightarrow \left(\frac{\gamma+1}{\gamma-1}\right)^2$$

Slit width ratio

* $$\boxed{\frac{W_1}{W_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \left(\frac{a_1}{a_2}\right)^2 = (\gamma)^2}$$

$$\boxed{\frac{a_1}{a_2} = \gamma}$$

$$\frac{a_1^2}{a_2^2} = \gamma^2$$

$$\boxed{\frac{I_1}{I_2} = \gamma^2}$$

Ratio of Intensity = Ratio of Slit width

If one of the slit width is four times of another then find the ratio of maximum and minimum Intensity of fringe's

$$\boxed{W_1 = 4W_2}$$

$$\frac{I_{max}}{I_{min}} = ?$$

$$\frac{I_{max}}{I_{min}} = \left(\frac{\gamma+1}{\gamma-1}\right)^2$$

$$\frac{I_{max}}{I_{min}} = \left(\frac{2+1}{2-1}\right)^2$$

$$\frac{I_{max}}{I_{min}} = \frac{9}{1}$$

$$\boxed{9:1}$$

$$\frac{I_1}{I_2} = \frac{W_1}{W_2} = \frac{4\cancel{W_2}}{\cancel{W_2}}$$

$$\boxed{\frac{I_1}{I_2} = 4} \quad \text{— (x)}$$

$$\boxed{\frac{I_1}{I_2} = \gamma^2} \quad \text{— (y)}$$

Comparing

$$\gamma^2 = 4$$

$$\boxed{\gamma = 2}$$

$$\frac{W_1}{W_2} = \gamma^2$$

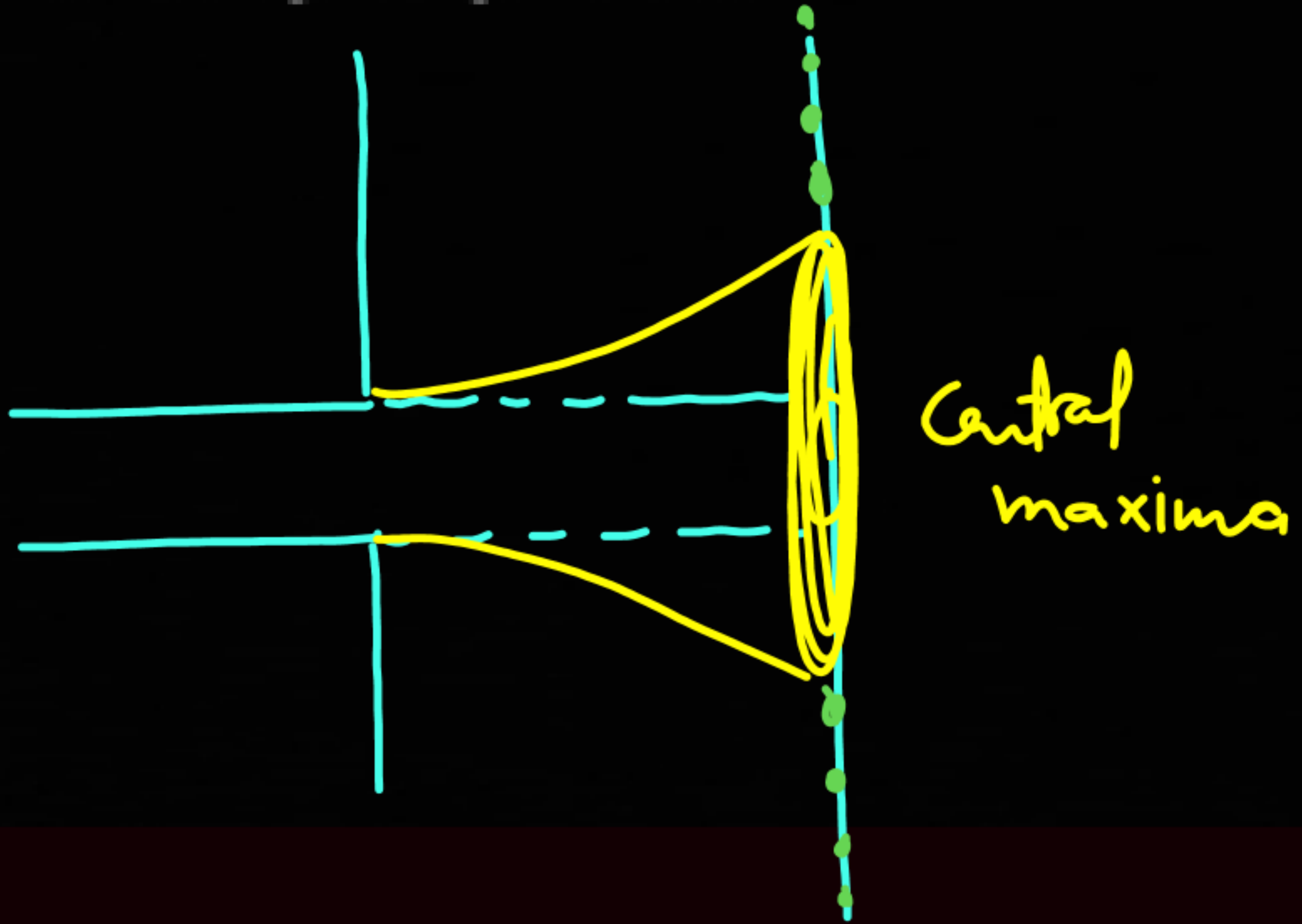
$$\frac{4W_2}{W_2} = \gamma^2$$

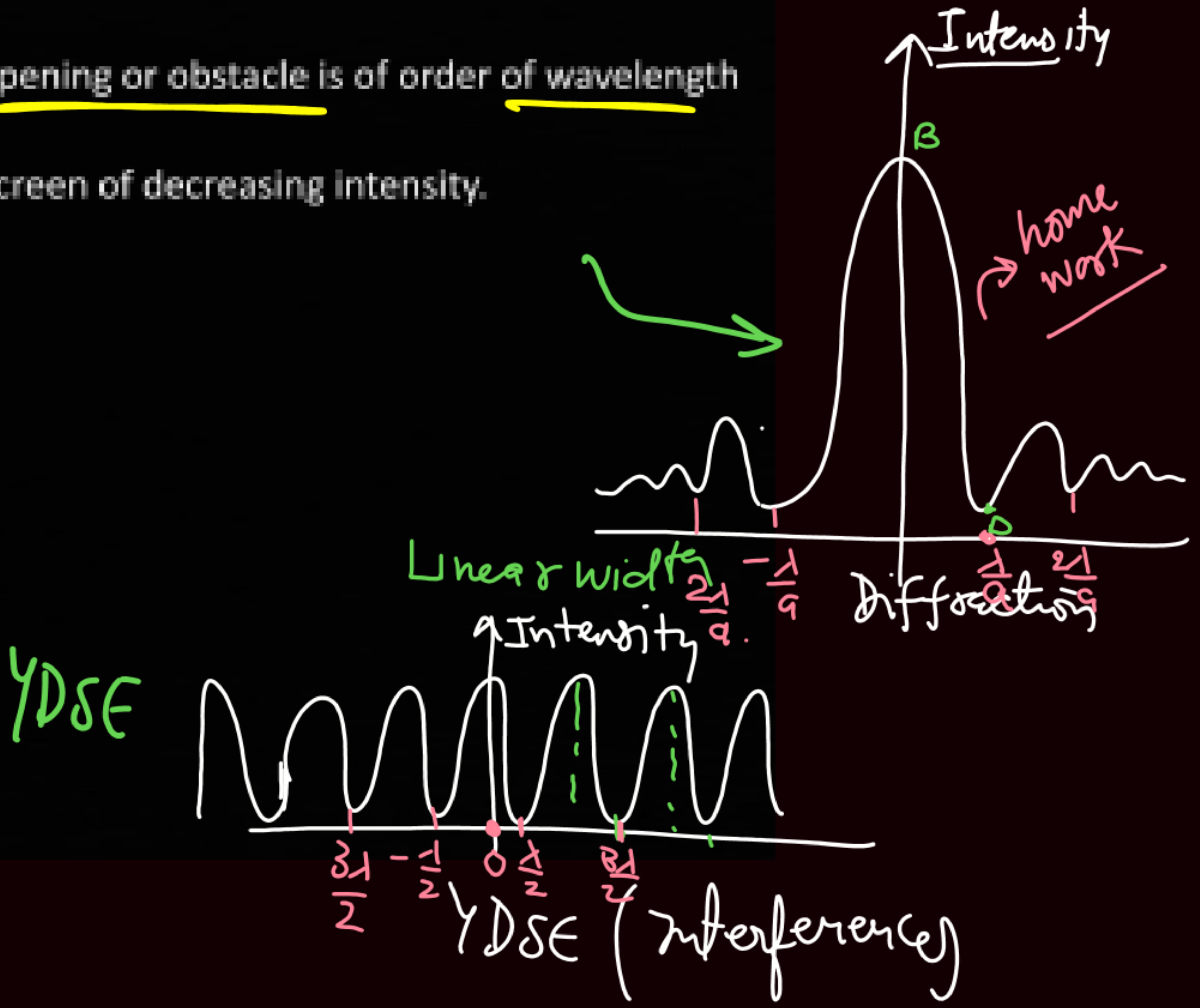
$$\gamma^2 = 4$$

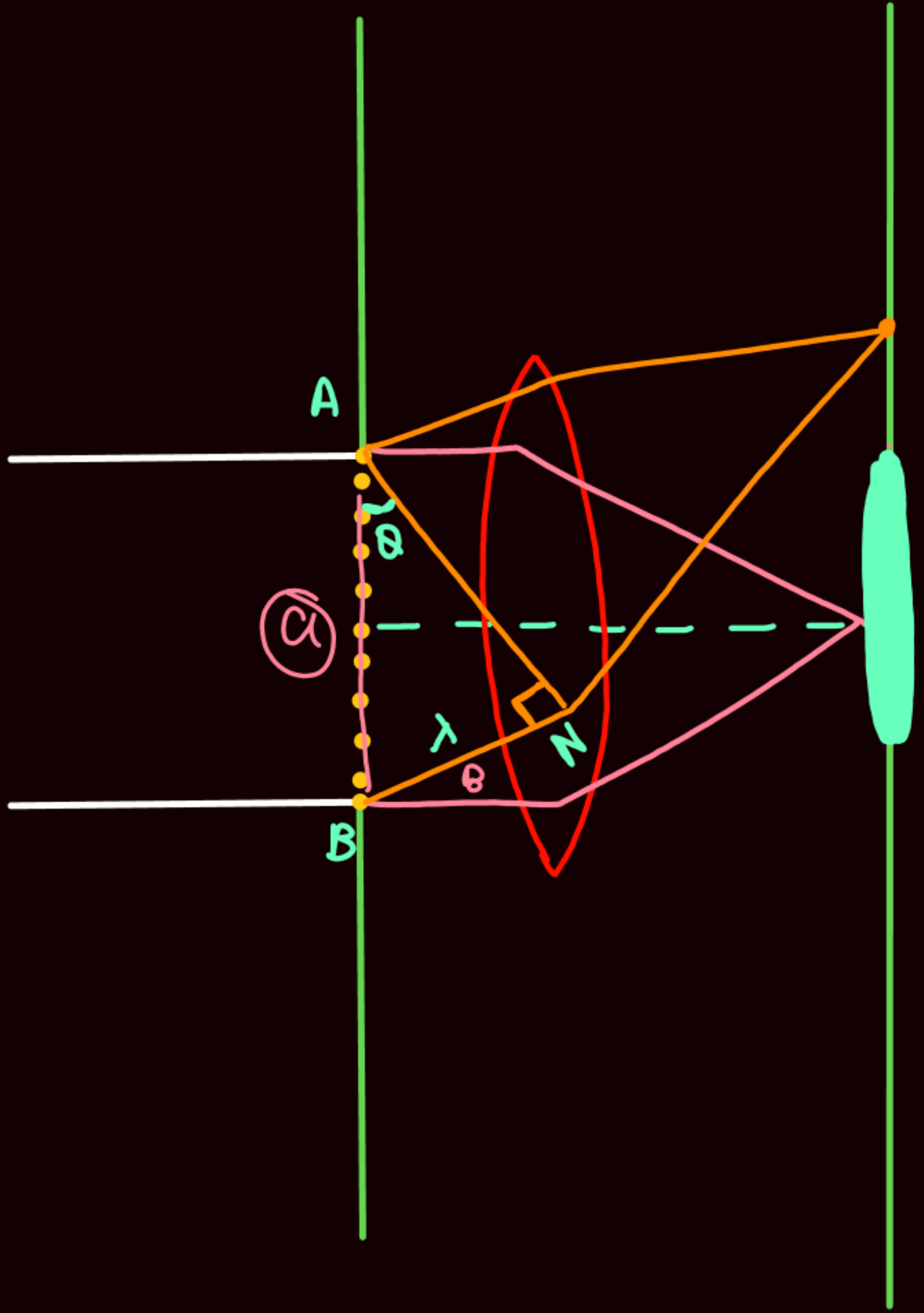
$$\boxed{\gamma = 2}$$

Diffraction of light-

- Diffraction of light is the phenomenon of bending of light around the corners of an obstacle and entering in the geometrical shadow region.
- Diffraction of light is more effective or noticeable when opening or obstacle is of order of wavelength of light.
- Alternate pattern of bright and dark fringe is formed on screen of decreasing intensity.
- Central fringe is brightest of all.







① position of minima

$$\boxed{\theta_n = \frac{n\lambda}{a}}$$

② Angular width of central maxima

$$\boxed{2\theta = \frac{2\lambda}{a}}$$

③ Total linear width of central maxima

$$\boxed{2x = \frac{2\lambda D}{a}}$$